

# Reconstructive REVIEW

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**Joint Implant Surgery and Research Foundation**

Strategic Alliance with



# Reconstructive REVIEW

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**Timothy McTighe, Dr. H.S. (hc)**

Executive Director, JISRF,  
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We are pleased to announce that JISRF's journal Reconstructive Review will become the official journal for APAS. We welcome its Members to open free access to all publications and encourage its Members to submit manuscripts for publication in one of four quarterly issues.

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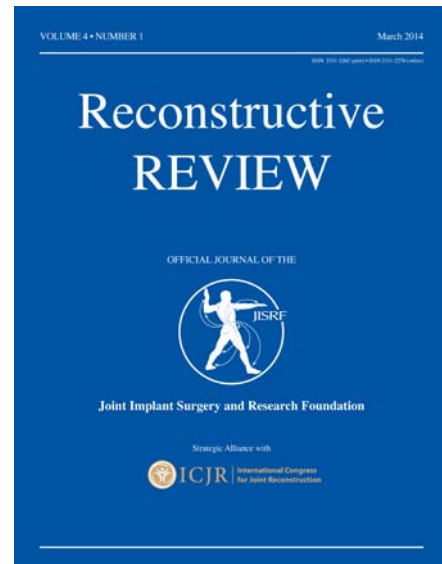
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DARF, founded in 2005 by Dr. Thomas K. Donaldson, has a focus on outcome studies and basic science with major emphasis on implant retrievals. His ongoing collaboration with Ian Clarke, PhD provides a synergy between the laboratory and clinical surgical science. Both men are Board Members of JISRF and have a significant working relationship with its Executive Director Timothy McTighe Dr. HS (hc).

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# Levels of Evidence

Reconstructive Review has adopted the American Academy of Orthopaedic Surgeons (AAOS) Levels of Evidence for Primary Research Question. These guidelines will now be part of the review process for manuscript submission.

**Levels of Evidence For Primary Research Question<sup>1</sup>**

	Types of Studies			
	Therapeutic Studies – Investigating the results of treatment	Prognostic Studies – Investigating the effect of a patient characteristic on the outcome of disease	Diagnostic Studies – Investigating a diagnostic test	Economic and Decision Analyses – Developing an economic or decision model
Level I	<ul style="list-style-type: none"> <li>High quality randomized trial with statistically significant difference or no statistically significant difference but narrow confidence intervals</li> <li>Systematic Review<sup>2</sup> of Level I RCTs (and study results were homogenous<sup>3</sup>)</li> </ul>	<ul style="list-style-type: none"> <li>High quality prospective study<sup>4</sup> (all patients were enrolled at the same point in their disease with ≥ 80% follow-up of enrolled patients)</li> <li>Systematic review<sup>2</sup> of Level I studies</li> </ul>	<ul style="list-style-type: none"> <li>Testing of previously developed diagnostic criteria on consecutive patients (with universally applied reference “gold” standard)</li> <li>Systematic review<sup>2</sup> of Level I studies</li> </ul>	<ul style="list-style-type: none"> <li>Sensible costs and alternatives; values obtained from many studies; with multiway sensitivity analyses</li> <li>Systematic review<sup>2</sup> of Level I studies</li> </ul>
Level II	<ul style="list-style-type: none"> <li>Lesser quality RCT (e.g. &lt; 80% follow-up, no blinding, or improper randomization)</li> <li>Prospective<sup>4</sup> comparative study<sup>5</sup></li> <li>Systematic review<sup>2</sup> of Level II studies or Level I studies with inconsistent results</li> </ul>	<ul style="list-style-type: none"> <li>Retrospective<sup>6</sup> study</li> <li>Untreated controls from an RCT</li> <li>Lesser quality prospective study (e.g. patients enrolled at different points in their disease or &lt;80% follow-up.)</li> <li>Systematic review<sup>2</sup> of Level II studies</li> </ul>	<ul style="list-style-type: none"> <li>Development of diagnostic criteria on consecutive patients (with universally applied reference “gold” standard)</li> <li>Systematic review<sup>2</sup> of Level II studies</li> </ul>	<ul style="list-style-type: none"> <li>Sensible costs and alternatives; values obtained from limited studies; with multiway sensitivity analyses</li> <li>Systematic review<sup>2</sup> of Level II studies</li> </ul>
Level III	<ul style="list-style-type: none"> <li>Case control study<sup>7</sup></li> <li>Retrospective<sup>6</sup> comparative study<sup>5</sup></li> <li>Systematic review<sup>2</sup> of Level III studies</li> </ul>	<ul style="list-style-type: none"> <li>Case control study<sup>7</sup></li> </ul>	<ul style="list-style-type: none"> <li>Study of non-consecutive patients; without consistently applied reference “gold” standard</li> <li>Systematic review<sup>2</sup> of Level III studies</li> </ul>	<ul style="list-style-type: none"> <li>Analyses based on limited alternatives and costs; and poor estimates</li> <li>Systematic review<sup>2</sup> of Level III studies</li> </ul>
Level IV	Case Series <sup>8</sup>	Case series	<ul style="list-style-type: none"> <li>Case-control study</li> <li>Poor reference standard</li> </ul>	<ul style="list-style-type: none"> <li>Analyses with no sensitivity analyses</li> </ul>
Level V	Expert Opinion	Expert Opinion	Expert Opinion	Expert Opinion

1. A complete assessment of quality of individual studies requires critical appraisal of all aspects of the study design.
2. A combination of results from two or more prior studies.
3. Studies provided consistent results.
4. Study was started before the first patient enrolled.
5. Patients treated one way (e.g. cemented hip arthroplasty) compared with a group of patients treated in another way (e.g. uncemented hip arthroplasty) at the same institution.
6. The study was started after the first patient enrolled.
7. Patients identified for the study based on their outcome, called “cases”; e.g. failed total arthroplasty, are compared to those who did not have outcome, called “controls”; e.g. successful total hip arthroplasty.
8. Patients treated one way with no comparison group of patients treated in another way.

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Our new website provides a more user friendly platform for viewing and searching all past and current articles. It's based on open source software called Open Journal Systems (OJS) created by the Public Knowledge Project.

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A Journal Published by the Joint Implant Surgery & Research Foundation



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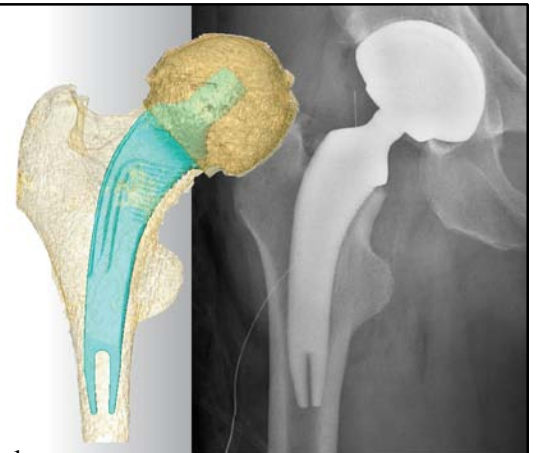


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- Case Reports
- Clinical/Surgical
- Commentary
- Controversial Issues (i.e. modularity, tapers, MoM)
- Reviews
- Letters to the Editor
- Surveys

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**If you require any assistance** please contact David Faroo, Managing Editor at [dfaroo@jisrf.org](mailto:dfaroo@jisrf.org).



## The Incidence of Dislocation Utilizing a Neck Sparing Stem in Primary THA in Community Based Practices with the Posterior Approach

McPherson E<sup>1</sup>, Vaughn B<sup>2</sup>, Keppler L<sup>3</sup>, Brazil D<sup>4</sup>, McTighe T<sup>5</sup>

### Abstract

This study retrospectively reviews the clinical results of a novel proximal neck-sparing cementless prosthesis for primary Total Hip Arthroplasty (THA). This neck-sparing prosthesis preserves the entire circumference of the femoral neck. The porous coated surface is located only within the femoral neck region. This study group included 338 primary THA's from three institutions. All approaches and techniques were similar, using a postero-lateral approach in all cases. Average follow-up was 38 months (range 12-56 months). There were five stem revisions (1.5%) in this group. Two stems were revised for aseptic loosening, two were revised for recurrent dislocation, and one was revised for a chronic periprosthetic infection employing a two-stage protocol. We had 3 dislocations (0.88%) and all three had re-operations. The neck sparing prosthesis is alluring as it saves almost the entire femoral neck and requires minimal deep posterior soft tissue releases. Our dislocation rate in this series was low. Insertion of a neck sparing prosthesis requires fastidious preparation and gentle insertion, but we find this design to provide reliable clinical function at short-term follow-up.

**Keywords:** THA, hip, arthroplasty, posterior approach, dislocation, neck sparing, and risk factors, primary  
**Level of Evidence:** AAOS Therapeutic Level III

### Introduction

Total hip arthroplasty (THA) is one of the most effective orthopedic procedures, providing consistently high success rates across all population segments—as measured by pain relief, improved function, and patient satisfaction [1,2,3,4,5]. As a result of these good outcomes, THA indications have been expanded to include younger and more active patients [6,7]. However younger patients are more likely to need revision surgery, and complications are higher with revision THA procedures [7,8,9].

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With the increased likelihood that younger patients will require a revision surgery later in life, it is advantageous to maximize proximal femoral bone stock to provide as much bone as possible for revision stem implantation [10]. Preservation of the entire femoral neck using a neck sparing prosthesis is a newer surgical technique that started in Italy and has now been widely used in the last decade [11,12]. Neck sparing implants potentially have the advantage of less thigh pain and are helpful to the surgeon when using a small incision approach. In addition, there is a mechanical advantage in retaining the femoral neck which results in a reduction of torsional forces placed on the implant / bone interface [1,13] (Figure 1). One potential problem with retaining a majority of the femoral neck is there is a chance for bony impingement. This can lead to residual pain, dysfunction, and possible dislocation. In this study we review the early clinical results utilizing a cementless proximal coated neck sparing femoral stem prosthesis. We wanted to assess our dislocation rate and clinical results from multiple surgery centers, all utilizing a postero-lateral surgical approach.

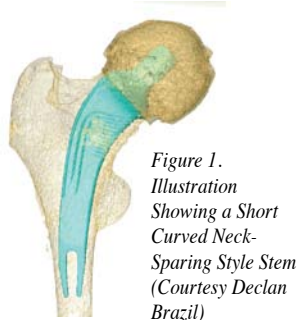


Figure 1. Illustration Showing a Short Curved Neck-Sparing Style Stem (Courtesy Declan Brazil)

## Material and Methods

Between April 2010 and June 2014 we performed 338 short-curved neck-sparing stems (ARC™ Stem, Omni, E. Tauton, MA) (Figure 2). The three senior authors (surgeons) utilized the postero-lateral approach on all cases [14]. All three surgeons along with the two additional co-authors were all involved with the early development of both the stem and instrumentation. Preoperative training with cadaver workshops was a requirement prior to any clinical surgical evaluation of this device (Figure 3). Intra-operative x-rays or fluoroscopy were also required in the early stage



Figure 2. Illustration Showing ARC™ Neck-Sparing Stem (Omni, E. Tauton, MA)



Figure 3. Cadaver Work Shop. (Courtesy JISRF Archives)

of surgical implantation (Figure 4). Limited weight bearing was advocated for the first 4-6 weeks since the porous coating is limited to the proximal portion of the stem that engages with the femoral neck.

The ARC stem design features a short curved titanium alloy stem with a novel conical flair for enhanced proximal compressive loading of the medial calcar (Figure 5). The proximal third of the stem has commercially pure titanium plasma spray coating with a surface layer of hydroxyapatite (HA) coating (25µm) to promote an early biologic bone healing to the implant. The modular femoral neck is made of cobalt chromium alloy and allows for intra-operative adjustment of joint stability, leg length and offset [15] (Figure 6).



Figure 4. Intraoperative X-Ray Showing Trial Rasp with Trial head/Neck and Cup in Place. (Courtesy JISRF Archives)



Figure 5. Illustration Showing the Proximal Conical flair of the Stem Designed to Provide Compressive Loading to the Medial Calcar of the Stem. (Courtesy JISRF Archives)



Figure 6. Picture of ARC™ Stem Showing Modular Necks in various positions (Valgus, Neutral & Versus) Co-Cr-Mo, Ceramic Head Taper 12/14, Titanium Alloy Stem with Proximal Porous Pure Titanium Plasma Spray Coating with a Surface Layer of HA Coating. (Courtesy JISRF Archives)

All acetabular components were a variety of cementless titanium alloy porous coated hemispherical designs and bearing surfaces. All head diameters were restricted to 32 mm or larger. In the smaller patient profile, if a 32 mm head size could not be reached, a dual mobility style implant was chosen. Early in this series two of our surgeons used a limited number of large metal on metal (MoM) bearings. The MoM bearing was discontinued due to rising concerns in the market with this type of bearing surface [16]. A total of 77 dual mobility acetabular components were used with 66 being the Active Articulation design (Biomet, Warsaw, IN) (Figures 7a, & b). The dual-mobility concept utilizes a 28mm femoral head that articulates and is locked into a

large polyethylene head. The large polyethylene bearing serves as a large head bearing that articulates within the all-metal monolithic cup.



Figure 7a. Picture of a dual mobility acetabular component (Active Articulation, Biomet, Warsaw, IN) (Courtesy McPherson)



Figure 7b. Postoperative X-Ray Showing ARC Stem with a Dual Mobility Cup. Notice Tight Femoral Canal (Dorr I) Distal Slot Pinched In. (Courtesy Keppeler)

## Surgical Technique for Neck Sparing Prosthesis

The neck sparing femoral stem essentially retains the femoral neck in its entirety up to the upper ¼ neck region. Using the postero-lateral approach to the hip, the superior one-half of the short external rotators are released from the posterior greater trochanter down to the base of the femoral neck. The capsule is preserved with transverse incisions made at the acetabular rim and the base of the femoral neck. A longitudinal capsular incision is made in between. This creates anterior and posterior capsular flaps that can be repaired at closure. Once the hip is dislocated, the femoral neck is resected 5 to 10 mm below the subcapital junction with a fine-toothed saw (Figure 8). The neck cut is based upon preoperative and intra-operative templating to restore head center of rotation. The neck sparing stem design and instrumentation is based upon following

the native medial curvature of the proximal femoral neck (Figures 9a, b, & c). Since the femoral neck cortical bone is distinctly thinner than the cortical femoral shaft, preparation of the proximal femur is more delicate. Rasping

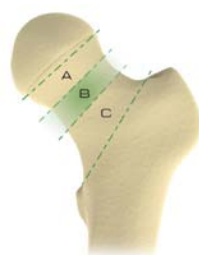


Figure 8. Illustration Showing Neck Resection Zones. Zone B being 5-10 mm as recommendation. (Omni Surgical Technique)

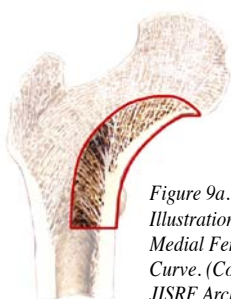


Figure 9a. Illustration Showing Medial Femoral Curve. (Courtesy JISRF Archives)



Figure 9b. Picture Showing Rasp Shaping Medial Femoral Curve to Stem Shape. (Courtesy JISRF Archives)



Figure 9c. Rasp and Femoral Stem Comparing Medial Curvature of the Stem. (Courtesy JISRF Archives)

is gentle and broaching is performed with a small mallet with frequent light impactions. Trialing of implants is performed with modular neck trials to optimize hip length, hip offset, and hip stability. Once definitive hip implants have been placed a meticulous posterior closure is performed. The hip capsule is closed as a separate layer. In all cases the hip capsule was closed from the superior acetabulum down to the prosthetic femoral neck. In some cases, where possible, the entire hip capsule was closed. The proximal short external rotators are repaired to the posterior greater trochanter with sutures placed into bone. All soft tissues are anatomically closed as best possible.

## Results

In our combined series there were 338 implanted short curved neck-sparing stems. Fifty-nine percent of patients were female and 41% were male. At an average follow-up of 38 months (range 12-56 months), Harris Hip Scores averaged 91.2 (range 78-100). There were three dislocations in this series (0.88%), all of which required revision surgery. In one case, the modular neck was exchanged to add 3.5mm in length and the acetabular polyethylene liner was also exchanged to add a 15° posterior hood. The stem was well fixed and retained. In the two other cases, the femoral stems were revised to conventional length stems, along with exchange of the modular acetabular polyethylene to add a posterior hood.

There were five stem failures in this study group. As noted above, two stems were revised for recurrent dislocation (0.6%). In both cases the femoral stems showed stable bony integration and were removed without difficulty. Two stems have been revised for aseptic loosening (0.6%).



They were both converted to conventional length primary hip stems. One stem was removed for chronic periprosthetic infection utilizing a two-stage protocol (0.3%). The stem was easily removed by making a circumferential femoral neck bone cut with a small sagittal saw at the lower 1/3 neck region. Bone loss was minimal (Figure 10). The overall revision stem rate in this series was 1.5%. There was also one acetabular cup revision for aseptic loosening in this series. In this case, the modular femoral neck was removed and exchanged in order to facilitate acetabular exposure (Figure 11).



Figure 10. Retrieved ARC Stem with Good Bone Attachment to Proximal Porous Coating. (Courtesy JISRF Archives)



Figure 11. Picture of Explanted Modular Neck. No signs of Corrosion. (Courtesy JISRF Archives)

In this series we were able to examine the seven modular necks that were either revised or exchanged. Even though these cases were revised relatively early in the life cycle of these implants, we observed no signs of corrosion between the modular femoral neck and the femoral stem body.

## Discussion

In the last decade there has been a push towards utilizing the anterior hip approach for THA [17]. Advocates of this approach have criticized the posterior approach for its higher rate of dislocation. Historically dislocation results in the posterior approach (with complete detachment of the external rotators) varied between (4.8% to 7%). Revision surgery for recurrent dislocation has a significant impact upon patient morbidity and psychological stress. Furthermore, it imparts a significant financial burden on the

healthcare system [18,19]. About 45% of dislocations occur within 4 weeks of surgery [19]. Various risk factors such as surgical approach, cup position, combined cup and stem anteversion, and femoral head size can impact clinical outcomes. However, the data supporting this view does not include more recent changes in surgical technique and implant technology. Recent changes that have reduced dislocation rates include careful preoperative templating to recreate joint center of rotation, neck-sparing implants that require little in posterior soft tissue releases, and finally techniques that emphasize a complete posterior soft tissue repair.

Restoration of hip mechanics is vital to providing optimal hip function and stability. Careful preoperative templating allows the surgeon to determine appropriate reaming depth for the acetabulum. Furthermore, careful templating determines lateral hip offset and vertical length as referenced from hip center. Preoperative templating facilitates intra-operative assessment and bone preparation for placement of THA implants. Even through preoperative templating is important, intra-operative templating with femoral neck measuring jigs must be utilized to corroborate preoperative measurements. Hip templating may provide false values especially when the arthritic hip is contracted into external rotation. In this position the femoral neck can appear more valgus and vertical. Offset can be underestimated as much as 7 to 10 mm depending on the rotation of the femur when an AP radiograph is used for templating [20,21].

Intra-operatively, trialing of implants is utilized to assess hip center, femoral offset, and neck length. Range of motion testing with trial implants is then required to determine combined anteversion of the cup-stem construct. For optimum range and stability, combined anteversion should be between 35 and 45 degrees [22]. Trialing is also performed to assess for bony impingement tested at end flexion with internal rotation as well as at end extension with external rotation. All impinging osteophytes and excess bone must be removed to maximize hip range without impingement and levering. Leg lengths must also be checked. Soft tissues are lax with a shortened leg and this makes the hip more prone to dislocation.

Short neck sparing stems are a new concept to the modern design armamentarium of hip implants in North America [1,23]. European surgeons have been working with these stems since the early 1980's, beginning with the pioneering work of Pipino in Italy [1,11,12] (Figure 12). The majority of European neck-sparing stems are



Figure 12. Illustration of Pipino Style Neck-Sparing Stem. (Courtesy JISRF Archives)

novel in that they preserve the entire circumference of the femoral neck and the implants follow the native curve of the proximal femoral neck. In contrast, in North America the newer short stem designs are just truncated versions of conventional style stems that cut into the proximal femoral neck and still load the femur in the metadiaphyseal region. The advantages of using short neck-sparing implants are several. First, nearly all of the proximal bone is preserved. This is advantageous when revision surgery is required. Removing a neck sparing prosthesis is facile and the revision stem required is similar to using a conventional primary hip implant. More importantly, the exposure for the neck sparing prosthesis requires only small deep tissue releases, preserving the deep tissues. This allows for a more robust posterior soft tissue repair. This is key to minimizing hip dislocation with the posterior approach. Finally, hip offset and neck-length are easier to restore. The neck-sparing prosthesis follows the native curve of the femoral neck rather than fitting into the medullary canal of the femur. By following the femoral neck it is far easier to restore native femoral offset and neck length. This is a key advantage that we feel enhances hip stability. With this surgical technique it is easier to gauge soft tissue tension as there has been minimal releases of soft tissues compared to the larger style approaches and releases needed for implantation of conventional stem designs.

This study strengthens our commitment to utilizing a short curved neck-sparing stem when possible. Our overall dislocation rate was 0.88%, which is encouraging. Despite using this stem design in highly active patients, our overall stem revision rate is acceptable at 1.5%.

One caveat with this implant design is the use of the modular femoral neck. Even though much of the femoral neck was preserved we still used a modular proximal neck to fine tune offset and



Figure 15. Postoperative X-Ray Showing ARC Stem with a Varus Modular Neck Position. (Courtesy JISRF Archives)

version (Figures 13, 14, & 15). Recent literature has cast disparaging results with modular necks in primary THA stems [24,25]. These reports impugn the modular neck junction as a source of debris from taper junction abrasion, fretting and corrosion. This debris is a source for creating a toxic reactive synovitis that can ultimately lead to pseudotumor formation [26]. Biomechanical studies demonstrate that for every

1mm increase of lateral offset from hip center, there is a 8% increase in torque placed upon the modular neck junction. Furthermore, for every 1mm increase in vertical offset from hip center, there is a 6% increase in torque placed upon the modular neck junction (Figure 16a). Therefore, when using a conventional stem seated into the medullary diaphyseal canal, the modular neck junction is far from the

>Per 1mm increase in true lateral ball-center offset increases torque by 8%

>Per 1mm increase of ball's neck-length increases torque by 6%

Offset	Neck-Length	Nm
35 mm	49.50	84
40mm	56.58	96
45mm	63.65	108
50 mm	70.72	120
55 mm	77.79	132

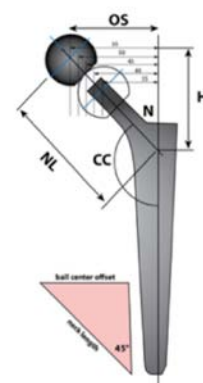


Figure 16a Chart Showing Torque Values for Femoral Offset and Neck Length. (Courtesy Ian Clarke)

hip center and torque forces upon the junction are high. In contrast, with the neck sparing hip prosthesis the modular neck junction, by virtue of preserving the femoral neck, is much closer to the hip center and modular neck stresses are significantly lower. This has been demonstrated in finite elemental analysis [27,29] (Figure 16b). This is also confirmed in this clinical study. In our 5 retrieved femoral stems we did not visualize any corrosion of the modular taper junction.

In summary, when using the neck sparing femoral stem we advocate head sizes between 32 to 36 mm. Neck skirts on the modular femoral heads are to be avoided at all costs. We do not recommend a modular head greater than 36mm



Figure 13. Postoperative X-Ray Showing ARC Stem with a Valgus Modular Neck Position. (Courtesy JISRF Archives)



Figure 14. Postoperative X-Ray Showing ARC Stem with a Neutral Modular Neck Position. (Courtesy JISRF Archives)

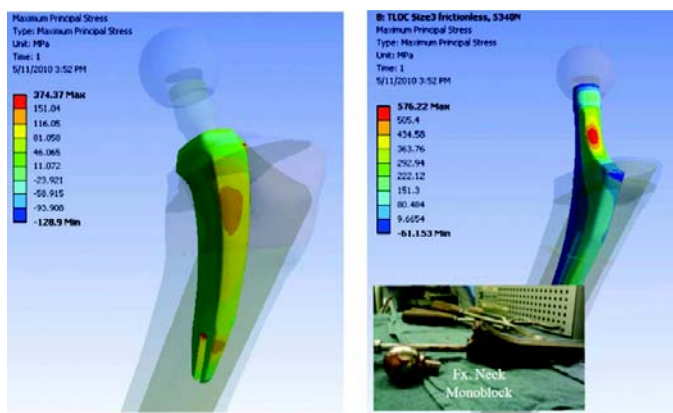


Figure 16b. FEA Model Showing 35% less Tensile Stress in the Neck-Sparing Stem versus that of a Tape-lock Style Stem. (Courtesy Declan Brazil)

as this can increase the torque loads upon the modular femoral neck junction. For small acetabular sockets, the dual articulation bearing is an acceptable alternative that provides a large head for stability. The majority of motion of the dual mobility construct is through the small 28mm ball and this reduces the torque stresses to the modular neck junction [28].

The advantage of proximal neck preservation with a neck-sparing stem is with the easy conversion to a standard diaphyseal engaging femoral stem if and when revision surgery is needed. We emphasize that there is a distinct learning curve to preparing and fitting a prosthesis in a completely intact femoral neck compared to a conventional diaphyseal engaging cementless stem. Preparation is fastidious and we strongly encourage the surgeon to attend a cadaver workshop and/or visit an experienced surgeon who is adept in this surgical procedure (Figure 17).



Figure 17. Postoperative X-Ray Showing Bilateral Hips. Left Showing a 1986 S-Rom Design and the Right Showing a 2010 ARC neck-Sparing Short Curved Stem Design. Both hips are in Place and Functioning Well. (Courtesy Keppler)

### Disclosure Statement:

One or more of our authors have disclosed information that may present potential for conflict of interest with this work. For full disclosures refer to last page of this journal.

### References:

- McTighe T, Brazil D, Keggi J, Keppler L, et al. "Short-Stem Designs for Total Hip Arthroplasty: Neck Stabilized Femoral Components". Callaghan J, Beaulé P, Clohisy J, Della Valle C, Rosenberg A, and Rubash H. The Adult Hip, 3rd ed. Philadelphia: Wolters Kluwer Health, in press.
- Engh CA Jr, Culpepper WJ, Engh CA. Long-term results of use of the anatomic medullary locking prosthesis in total hip arthroplasty. J Bone Joint Surg Am. 1997;79:177-184.
- Moussa H, Pierre B, Jacques D, et al. Alumina-on-alumina total hip arthroplasty: A minimum 18.5 year follow-up study. J Bone Joint Surg Am. 2002;84(1):69-77.
- Neumann L, Freund KG, Sørensen K H. Long-term results of Charnley total hip replacement. Review of 92 patients at 15 to 20 years. J Bone Joint Surg Br. 1994;76(2):245-251.
- Teloken MA, Bissett G, Hozack WJ, et al. Ten to fifteen-year follow-up after total hip arthroplasty with a tapered cobalt-chromium femoral component (tri-lock) inserted without cement. J Bone Joint Surg Am. 2002;84-A(12):2140-2144.
- Polkowski et al. Total Hip Arthroplasty in the very Young Patient." Journal of the American Academy of Orthopaedic Surgeons. (2012). , 20, 487-497.
- Girard J, Glorion C, Bonnomet F, et al. Risk factors for revision of hip arthroplasties in patients younger than 30 years. Clin Orthop Relat Res. 2011;469(4):1141-1147.
- Haveri S, Uppin RB. Results of Uncemented Total Replacement Done in Very Young Patients. Int Surg J. 2014 Aug; 1 (2):80-83 pISSN 2349-3305 | eISSN 2349-2902
- Dorr LD, Luckett M, Conaty JP. Total hip arthroplasties in patients younger than 45 years. A nine- to ten-year follow-up study. Clin Orthop Relat Res. 1990;(260):215-219.
- McTighe T, Brazil D, et al. The Science Behind a Short (Neck Preserving) Curved Stem Total Hip Replacement. Poster ID: EFFORT 14-4564, June 2014 London, UK.
- Pipino F, Molfetta L, Grandizio M. Preservation of the femoral neck in hip arthroplasty: Results of a 13- to 17-year follow-up. J Orthop Traumatol. 2000;1:31-39.
- Pipino F. J Orthopaed Traumatol (2004) 4:165-171. DOI: <http://dx.doi.org/10.1007/s10195-004-0065-2>
- Freeman M. Why Resect The Neck? JBJS Vol. 68 B. No. 3, May 1986
- Hoppenfield S, DeBoer P. Surgical Exposures in Orthopaedics: The Anatomic Approach. 2nd Ed. Philadelphia, PA: J.B. Lippincott Company; 1994.
- Keppler L, McTighe T, Brazil D, The Role of Stem Modularity for THA in a Community Based Practice. RR, Vol2, No2 (August 2012) P16-26, DOI: <http://dx.doi.org/10.15438/rr.v2i2.10>
- McTighe T, Mayor M, Stulberg B, Donaldson T, Keggi J, Keppler L, Clarke I, McPherson E, Interview on Metal on Metal Bearings. RR, Vol 2, No 2 (August 2012) DOI: <http://dx.doi.org/10.15438/rr.v2i2.19>
- Matta JM, Shahrdar C, Ferguson T. Single-Incision Anterior Approach for Total Hip Arthroplasty on an Orthopaedic Table. Clin Orthop Rel Res. 2005; 441: 115-24.
- Dudda M, Gueleryuez A, et al. Risk Factors for Early Dislocation after Total Hip Arthroplasty: A Match Case-Control Study. J. Orthop Surg 2010;18(2):179-83
- Chandler RW, Dorr LD, Perry J. The functional cost of dislocation following total hip arthroplasty. Clin Orthop Relat Res. 1982;168:168-172.
- Schutte HD, Conrad J, Barfield W, Conway W, McTighe T. Femoral Offset How to Measure Preoperatively. Oral paper, Research on Modularity Hip Scientific Meeting Oct. 2009 www.jisrf.org DOI: <http://dx.doi.org/10.13140/RG.2.1.4683.1203>
- Schutte HD, Conrad J, Barfield W, Conway W, McTighe T. Predicting Errors in Offset Templating for THA. Poster 59 ICJR CME Course April 2012 Coronado, CA. www.jisrf.org DOI: <http://dx.doi.org/10.13140/RG.2.1.1673.8408>
- Dorr LD, Malik A, Dastane M, Wan Z. Combined Anteversion Technique for Total Hip Arthroplasty. Clin Orthop Rel Res. 2009; 467(1): 119-27.
- McTighe T, Woodgate I, Turnbull A, et al. A New Approach To Neck-Sparing THA Stem. AAOS Poster Exhibit 32, March 2008, San Francisco, CA. DOI: <http://dx.doi.org/10.13140/RG.2.1.1799.5367>
- Berry DJ. Utility of Modular Implants in Primary Total Hip Arthroplasty. The Journal of Arthroplasty 29 (2014) 657-658
- McTighe T, Brazil D, Bruce W. Metallic Alloys in Total Hip Arthroplasty. In: Cashman J, Goyal N, Parvizi J, eds. The Hip: Preservation, Replacement and Revision. Baltimore, MD: Data Trace Publishing Company; 2015:14-1—14-12.
- Hsu A, Gross C, Levine B. Pseudotumor From Modular Neck Corrosion After Ceramic-on-Polyethylene Total Hip Arthroplasty. Am J Orthop. 2012;41(9):422-426.
- Brazil D, McTighe T. Taper Issues in THA. Oral Paper ICJR, Sydney, Australia-Feb14, 2014, DOI: <http://dx.doi.org/10.13140/RG.2.1.4426.3521>
- McPherson EJ, Sherif SM. In Vivo Dissociation of a Dual Articulation Bearing in Revision THA: A Case Report. Journal of Reconstructive Review. 2012; 2(2): 72-76. DOI: <http://dx.doi.org/10.15438/rr.v2i2.18>
- Brazil D, McTighe T, et al. FEA Analysis of Neck-Sparing Versus Conventional Cementless Stem. RR October 2011. DOI: <http://dx.doi.org/10.15438/rr.v1i1.2>





## Biomechanical Alignment of Main Wear-Pattern on MOM Total Hip Replacement

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### Abstract

In the majority of retrievals, femoral heads and cups are sent for analysis with no designation as to positioning in-vivo. In addition, when patients retain the femoral prosthesis, evidence of neck impingement damage is lost. In this case report we studied head and cup wear-patterns and stripe damage in a novel case that included a large diameter metal-on-metal THA that was retrieved with the head still fused to the stem. This provided anatomical positioning of head wear-pattern and stripe damage as represented by the orientation of the femoral stem in radiographic images. We investigated (1) size, shape and location of head and cup wear-patterns, (2) cup-to-stem impingement damage, and (3) head stripe-wear. The head wear-pattern was elliptical in shape, 40mm diameter with area covering 2200 sq.mm. Its hemispherical ratio was 56% with aspect ratio 1.2 and typical of large-diameter MOM retrievals. Wear-pattern extended from 12° above superior head-margin to approximately 40° inferior to polar axis. Centroidal vector in coronal plane was 13° posterior to polar axis and in transverse plane was 19° superior to polar axis. These vector data corresponded well with biomechanical predictions of resultant load axes in gait studies. Stripe damage was identified on the head, and the cup rim could thereby be aligned to verify neck impingement and also head subluxation mechanisms. Cup wear-pattern was not centrally contained, indicating this patient had experienced repetitive edge-wear during gait. Thinning of the cup rim by 350- 400µm indicated that posterior impingement with repetitive anterior subluxation of the head had created this edge-wear.

**Keywords:** wear-pattern, alignment, metal-on-metal, heads, total hip

**Level of Evidence:** AAOS Therapeutic Level IV

### Introduction

Contemporary MOM bearings offered perceived benefits of lower wear compared to metal-on-polyethylene and with use of large-diameter heads offered additional benefits of greater motion and superior stability [1,2]. With a variety of designs and both positive [3-5] and negative reports [6-10] now emerging with regard to MOM in both total hip arthroplasty (THA) and resurfacing arthroplasty (RSA), many studies have focused on issues regarding

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metal alloys, cup design, surgical positioning [11-13] and effects of “edge loading” [7,9,14-19].

From studies of retrieved ceramic-on-ceramic (COC) bearings it was apparent that there were two types of wear patterns in THA. The anticipated ‘normal’ mode of everyday activities [20,21] created more or less circular wear patches on the head and inside the cup [22,23]. However, COC cases with 1 to 22 years follow-up also revealed evidence of a crescent-shaped type of stripe wear across femoral heads and around the rims of ceramic cups [22,24-27]. The latter wear damage was attributable to edge-wear of ceramic cups. Retrieval studies of large diameter MOM bearings also revealed these normal wear patterns, termed main wear zones (MWZ), on both heads and cups [28-30]. Evidence of stripe wear mechanisms appeared to indicate 3rd-body wear damage, plastic deformation due to rim impingement, or both phenomena [31,32].

In the majority of retrieval cases, retrieved femoral heads and cups are sent for analysis with no designation as to their original anatomical positioning. In addition, when patients retain the femoral prosthesis, the signs of impingement damage on femoral necks are lost. We therefore sought evidence of wear patterns and stripe wear mechanisms in a large diameter THA that was retrieved with the head still fused to the femoral stem. This gave us the anatomical position of the femoral head as represented by the orientation of the stem. We investigated (1) size, shape and location of the MWZ areas on the femoral head and cup, (2) damage from cup-to-stem impingement, and (3) stripe damage.

### Consent

The patient signed an IRB approved consent allowing review of her records and analysis of her hardware as well as verbally consented to publication of her case.

## Materials and Methods

A primary MOM total hip was performed in February 2008 on a 35 year old female patient (BMI 38.5) for avascular necrosis. Medical history included a single seizure associated with a febrile illness seven years prior to her hip replacement surgery. X-ray images demonstrated acetabular cup position with 55° inclination and 39° anteversion estimated from the AP pelvis radiograph (Figure 1). Eight months postoperatively the patient developed headaches, memory loss, vertigo, and aura-like symptoms which progressed to seizures and she consulted with a neurologist. At 12 months postoperatively, the patient presented with progressive hip pain and sounds of “popping”, gross creak-



Figure 1: Pre-revision AP pelvis of left hip prosthesis. Cup inclination was measured as 55° and anteversion calculated as 39° using this view

ing, and crepitus sensations with motion. Blood samples were collected at this time, revealing her serum cobalt level was 126.8 ppb and her serum chromium level was 64 ppb. Her ultrasound showed a small fluid collection along the femoral head and neck (2.4x3.9 cm) and the echocardiogram was positive for mild mitral and trace tricuspid regurgitation. There was no change in component position and there was no evidence of loosening or osteolysis.

Revision surgery was performed at 32 months postoperatively (November 2010). At surgery, upon entering the hip capsule a dark, serous fluid was observed along with synovitis. The implants were well fixed. Several attempts were made to remove the femoral head in order to retain the well-fixed stem. However, the head appeared fused to the trunnion and a femoral osteotomy was performed to remove the stem. Synovial tissue and capsule were sent to pathology along with the dark, serous fluid for culture. The pathologist reported all cultures were negative and the histology indicated an inflammatory response consistent with aseptic lymphocyte-dominated vasculitis-associated lesion (ALVAL).

Following revision, the patient's mental status normalized and headaches and seizures stopped. Her serum cobalt level gradually declined and 11 months after revision it measured 1.1 ppb. The patient has had some persistent hip pain since the revision surgery, possible related to her lumbar spine disease.

Retrieved components included a 50mm Magnum head (modular -3mm taper adapter), a M2a Magnum cup (56mm outer diameter), and a lateralized Taperloc stem (Porous coated, size 10 x 140mm, Biomet, Warsaw, IN). The components were studied visually by stereo-microscopy, white-light interferometry (WLI: NewView 600 Zygo Corp.), and scanning electron microscopy (SEM: EVO

MA 15, Zeiss). Surface features were graded visually and verified by stereo-microscopy. Wear patterns (MWZ) were measured by included angles and both MWZ area and hemispherical-area ratio (%Hemi) were calculated [31]. Centroidal vectors were calculated by measuring the arcs of the wear pattern in multiple views (Figure 2). The cup MWZ extended up to the cup rim, representative of ‘edge-

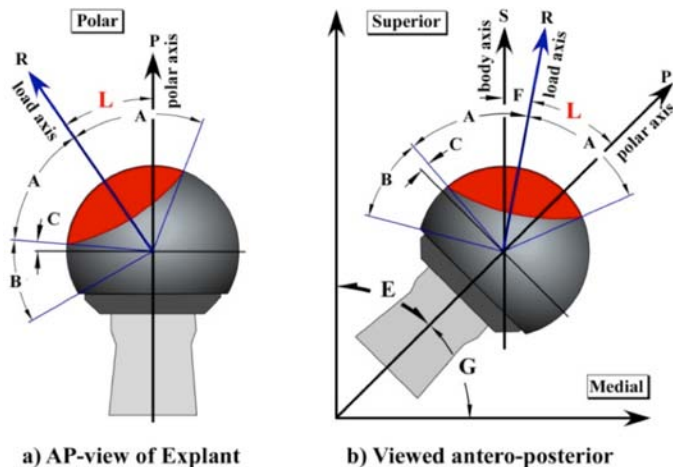


Figure 2: Representative model to calculate the vectors and the axis on the head.

wear’, and assessed by the rim-bearing angle. SEM and energy-dispersive spectroscopy (EDS: Bruker, Inc.) were used to investigate surface details and possible material transfer.

## Results

This retrieval was novel because the fused head revealed the exact orientation of the MWZ in vivo. This was elliptical in shape and extended from  $12^\circ$  above the superior edge to approximately  $40^\circ$  inferior of the polar axis. The MWZ was approximately 40mm in diameter, with 2200mm<sup>2</sup> area. The MWZ hemispherical ratio was 56% with aspect ratio 1.2, typical of MOM retrievals [31]. In the coronal plane, the centroidal vector was approximately  $13.3^\circ$  posterior to the polar axis and in the transverse plane, the centroidal vector was approximately  $18.8^\circ$  superior to the polar axis (Figure 3).

The cup had not been marked at revision so the orientation in vivo was unknown. The orientation was estimated based on experience with our previous study of 60 MOM retrievals [31]. The cup MWZ extended up to the rim over a  $157^\circ$  arc (Figure 4). It descended approximately 36mm into the cup, and covered an area of 1275mm<sup>2</sup>. Thinning of the cup rim and loss of the cup ‘bevel’ was identified in a  $90^\circ$  arc inferiorly (Figure 4).

Stripe wear was identified on the femoral head and the cup rim could be aligned with to verify both neck impinge-

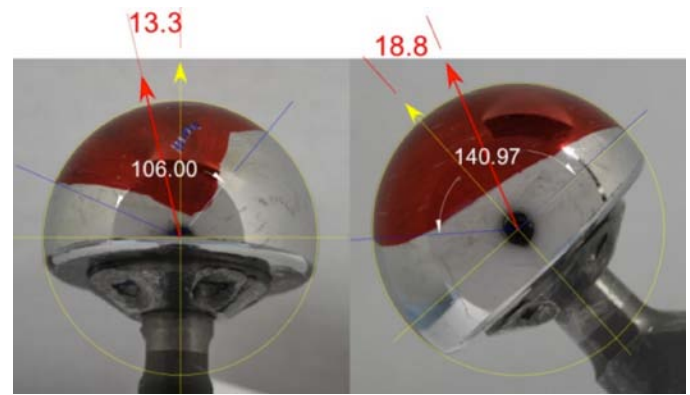


Figure 3: Coronal and transverse views of fused femoral head to calculate centroidal vectors of MWZ.

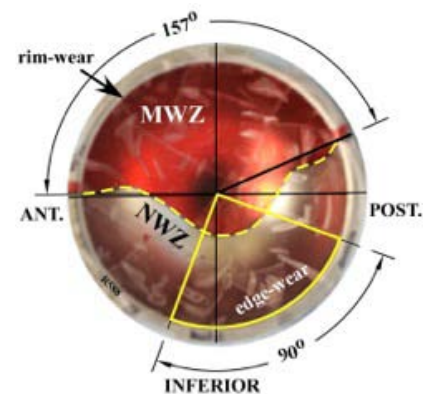


Figure 4: Cup MWZ had  $157^\circ$  arc across the superior rim, while thinning of cup edge extended over  $90^\circ$  arc inferiorly.

ment and head subluxation mechanisms. Although stripe wear was readily identified by SEM (Figure 5), details of head wear-patterns were greatly obscured by metallic contaminating layers. EDS-imaging identified Fe and Ni elements, typical of stainless-steel instruments used during the revision operation (figure 6). Circumferential markings on the posterior femoral neck represented damage caused by the cup rim during impingement (Figure 7). Thinning of the cup rim by 350-400μm (Figure 4) indicated that posterior impingement resulted in repetitive anterior subluxation of the femoral head, thereby creating edge wear.

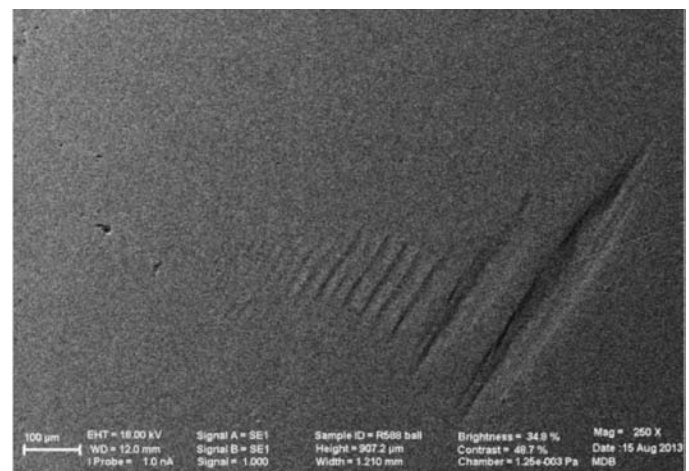


Figure 5: SEM imaging of approximately 50μm grooves in head's polar region.



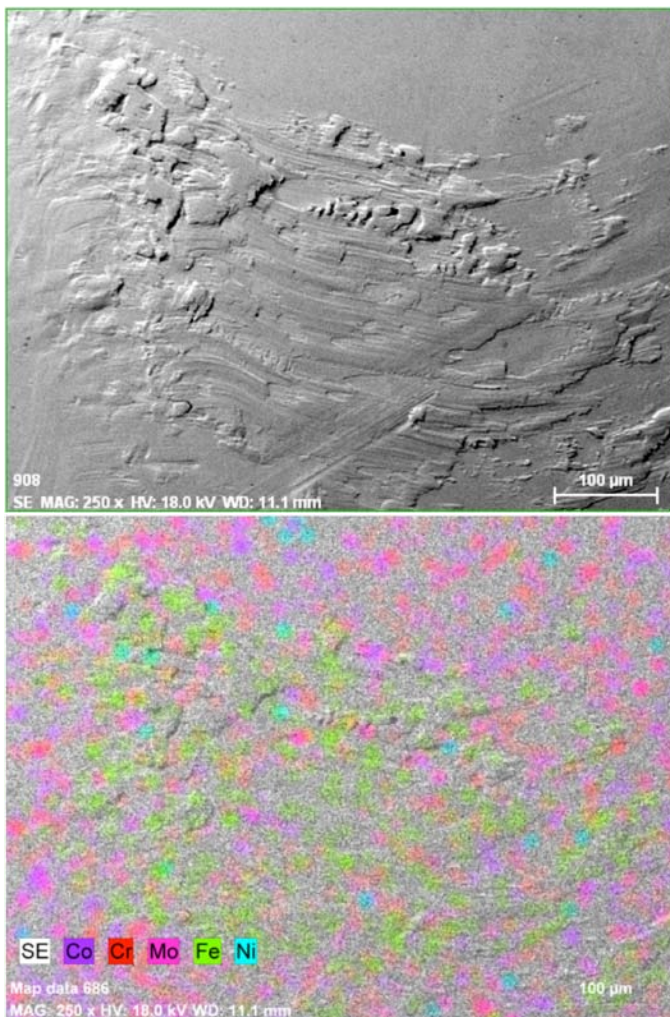


Figure 6: SEM image of contamination of the CoCr head. EDS identified iron and nickel, indicating stainless steel from instruments used during surgery.

## Discussion

Wear analysis can be severely limited by the fact that retrieved bearings seldom come marked to identify positioning in vivo [33]. With MOM bearings it was possible to identify the normal wear patterns in hip simulator studies [34]. Our underlying assumption for the modular femoral heads that came with no markings was that the narrowest margin between the wear pattern and the base of the femoral head represented the superior site (Fig. 3b). We applied this method to MOM retrieval studies to identify the wear patterns created in vivo and thereby deduce the implant orientations [31,35]. This also became a prerequisite



Figure 7. Impingement of cup on neck was verified by aligning cup rim to the circumferential neck markings and noting the rim was juxtaposed to polar stripes on head.

for determining stripe wear locations produced on femoral heads, where the cups reached extremes of hip motion. This 50mm MOM case was loaned to the DARF Center with the femoral head fused to the trunnion. It was therefore an ideal opportunity to evaluate head and cup wear patterns and relate these to their radiographic orientations.

Head wear-patterns were subtended by angles of  $106^\circ$  and  $141^\circ$  in the transverse and coronal planes, respectively. This indicated that the patient had not achieved full range of flexion, thought to be due to her posterior impingement. The MWZ centroidal vectors on the head wear pattern were positioned at  $18.8^\circ$  in the coronal plane and  $13.3^\circ$  in the transverse plane. The former corresponded well with the average  $16^\circ$  centroidal-area vector (CA) in the prior retrieval study [31]. Assuming a femoral head at a neutral inclination of  $45^\circ$  and a femoral stem oriented at  $8^\circ$  to the vertical, this wear pattern would be orientated  $19^\circ$  medial to the vertical plane. This corresponded well with biomechanical predictions from gait studies and from instrumented prostheses [36,37]. Following analysis, the head was successfully removed using the appropriate instrumentation.

In this retrieval, much of the stripe wear damage was obscured by stainless steel contamination originating from instrumentation used during revision surgery. Nevertheless the SEM analysis did indicate polar stripe damage indicative of impingement at extremes of hip excursion. This was confirmed by the circumferential neck marking indicative of impingement by the cup rim, these being distinct from damage produced by head removal attempts. The asymmetry in the wear pattern also indicated that impingement had been a habitual occurrence.

The cup with  $55^\circ$  lateral inclination would not be considered adversely positioned. Nevertheless the wear pattern in the cup was not well contained, i.e. it extended up to the cup rim and circumferentially. Therefore this patient had experienced edge wear during gait and extensive cup thinning was evident, thought to be due to the repetitive subluxation of the femoral head during impingement. Thus there were multiple implant sites capable of releasing metal debris [35]. Trunnion fretting and corrosion aspects are not discussed here, being the subject of a follow-up paper.

In conclusion, this MOM retrieval with a fused head provided confirmation of the manner in which we use wear patterns on heads and cups to deduce implant orientation in vivo. Wear patterns on femoral heads provide a good indication of habitual wear in vivo while cup wear patterns provide insight as to whether the wear was contained centrally in the cup (ideal) or in fact demonstrated adverse edge wear. Implant orientation is also a prerequisite to interpreting significance of stripe damage on heads and whether or

not it relates to possible cup-to-neck impingement positions creating an edge wear mechanism. This makes stripe analysis possible, even when the femoral stem is not available for inspection.

### Disclosure Statement:

The authors of this article have disclosed that there is no potential for conflict of interest with this work and no benefits or funds were received in support of this paper. For full disclosures refer to last page of this journal.

### References

- Zahiri CA, Schmalzried TP, Ebrahmdadeh E, Szuszczewicz ES, Salib D, Kim C, Amstutz HC. Lessons learned from loosening of the McKee-Farrar metal-on-metal total hip replacement. *J Arthroplasty* 1999;14-3:326-32.
- Amstutz HC, Grigoris P, Dorey FJ. Evolution and future of surface replacement of the hip. *J Orthop Sci* 1998;3-3:169-86.
- Amstutz HC, Le Duff MJ, Harvey N, Hoberg M. Improved survivorship of hybrid metal-on-metal hip resurfacing with second-generation techniques for Crowe-I and II developmental dysplasia of the hip. *J Bone Joint Surg Am* 2008;90 Suppl 3:12-20.
- Daniel J, Ziaee H, Kamali A, Pradhan C, Band T, McMin DJW. Ten-year results of a double-heat-treated metal-on-metal hip resurfacing. *J Bone Joint Surg Am* 2010;92B:20 - 7.
- Amstutz HC, Le Duff M, Johnson AJ. Socket position determines hip resurfacing 10-year survivorship. *Clinical Orthopaedics and Related Research* 2012;470:3127 - 33.
- Glyn-Jones S, Pandit H, Kwon YM, Doll H, Gill HS, Murray DW. Risk factors for inflammatory pseudotumour formation following hip resurfacing. *J Bone Joint Surg Br* 2009;91-B:1566-74.
- Langton D, Jameson S, Joyce T, Hallab N, Natsu S, Nargol A. Early failure of metal-on-metal bearings in hip resurfacing and large-diameter total hip replacement. A consequence of excess wear. *Journal of Bone and Joint Surgery Br* 2010;92-B:38 - 46.
- Hart AJ, Hester T, Sinclair K, Powell JJ, Goodship AE, Pele L, Fersht NL, Skinner J. The association between metal ions from hip resurfacing and reduced T-cell counts. *J Bone Joint Surg Br* 2006;88-4:449-54.
- De Smet K, De Haan R, Calistri A, Campbell PA, Ebrahmdadeh E, Pattyn C, Gill HS. Metal ion measurement as a diagnostic tool to identify problems with metal-on-metal hip resurfacing. *J Bone Joint Surg Am* 2008;90 Suppl 4:202-8.
- MHRA. Press release: MHRA issues new advice to surgeons about metal-on-metal total hip replacements. Medicines and Healthcare products Regulatory Agency, 2012.
- Shimmin AJ, Walter WL, Esposito C. The influence of the size of the component on the outcome of resurfacing arthroplasty of the hip. *Journal of Bone and Joint Surgery BR* 2010;92 -B:469 - 76.
- Griffin WL, Nanson CJ, Springer BD, Davies MA, Fehring TK. Reduced articular surface of one-piece cups. A cause of runaway wear and early failure. *Clin Orthop Relat Res* 2010;468:2328 - 32.
- Murray D, Grammatopoulos G, Gundle R, Gibbons CL, Whitwell D, Taylor A, Glyn-Jones S, Pandit HG, Ostlere S, Gill H, Athanasou NA, McLardy-Smith P. Hip resurfacing and pseudotumour. *ISSN* 2011:279 -83.
- Langton DJ, Sprowson AP, Joyce TJ, Reed M, Carlisle I, Partington P, Nargol AV. Blood metal ion concentrations after hip resurfacing arthroplasty: a comparative study of articular surface replacement and Birmingham Hip Resurfacing arthroplasties. *J Bone Joint Surg Br* 2009;91-10:1287-95.
- Morlock MM, Bishop M, Zustin J, Hahn M, Ruther W, Amling M. Modes of Implant Failure After Hip Resurfacing: Morphological and Wear Analysis of 267 Retrieval Specimens. *J Bone Joint Surg Am* 2008;90:89 -95.
- Mellon SJ, Kwon YM, Glyn-Jones S, Murray DW, Gill HS. The effect of motion patterns on edge-loading of metal-on-metal hip resurfacing. *Medical Engineering & Physics* 2011;33:1212 - 20.
- Kwon YM, Mellon SJ, Monk P, Murray DW, Gill HS. In vivo evaluation of edge-loading in metal-on-metal hip resurfacing patients with pseudotumours. *Bone Joint Res.* 2012;1-4:42 -9.
- Underwood RJ, Zografos A, Sayles RS, Hart A, Cann P. Edge loading in metal-on-metal hips: low clearance is a new risk factor. *J Eng in Med* 2012;226-3:217 - 6.
- De Haan R, Pattyn C, Gill HS, Murray DW, Campbell PA, De Smet K. Correlation between inclination of the acetabular component and metal ion levels in metal-on-metal hip resurfacing replacement. *J Bone Joint Surg Br* 2008;90-10:1291-7.
- McKellop HA, Campbell P, Park SH, Schmalzried TP, Grigoris P, Amstutz HC, Sarmiento A. The origin of submicron polyethylene wear debris in total hip arthroplasty. *Clin Orthop* 1995-311:3-20.
- McKellop HA, ed. Distinguishing among wear modes, wear mechanisms and wear damage in prosthetic joints. 2011:103 - 13.
- Shishido T, Clarke IC, Williams P, Boehler M, Asano T, Shoji H, Masaoka T, Yamamoto K, Imakiire A. Clinical and simulator wear study of alumina ceramic THR to 17 years and beyond. *J Biomed Mater Res* 2003;67B-1:638-47.
- Tateiwa T, Clarke IC, Pezzotti G, Sedel L, Kumakura T, Shishido T, Yamamoto K. Surface micro-analyses of long-term worn retrieved "Osteal (TM)" alumina ceramic total hip replacement. *Journal of Biomedical Materials Research Part B-Applied Biomaterials* 2007;83B-2:562-70.
- Dorlot JM, Christel P, Meunier A. Wear analysis of retrieved alumina heads and sockets of hip prostheses. *J Biomed Mater Res* 1989;23-A3 Suppl:299-310.
- Nevelos JE, Ingham E, Doyle C, Fisher J, Nevelos AB. Analysis of retrieved alumina ceramic components from Mittelmeier total hip prostheses. *Biomaterials* 1999;20-19:1833-40.
- Walter WL, Insley GM, Walter WK, Tuke MA. Edge loading in third generation alumina ceramic-on-ceramic bearings: stripe wear. *J Arthroplasty* 2004;19-4:402-13.
- Manaka M, Clarke IC, Yamamoto K, Shishido T, Gustafson A, Imakiire A. Stripe wear rates in alumina THR-comparison of microseparation simulator study with retrieved implants. *J Biomed Mater Res* 2004;69B-2:149-57.
- McKellop H, Park S, Chiesa R, Doorn P, Lu B, Normand P, Grigoris P, Amstutz H. In vivo wear of 3 types of metal on metal hip prostheses during 2 decades of use. *Clinical Orthopaedics and Related Research* 1996;329S:128 - 40.
- Glyn-Jones S, Roques A, Gill R, Taylor A, Whitwell D, Esposito C, Walter W, Tuke M, Murray D. Metal on metal hip resurfacing arthroplasty-related pseudotumours are associated with increased bearing surface wear, caused by impingement and edge-loading. 56th Annual Meeting of the ORS. 2010:Poster No. 2164.
- Tuke M, Taylor A, Roques A, Maul C. 3D linear and volumetric wear measurement on artificial hip joints - Validation of a new methodology. *Precision Engineering*. Elsevier, 2010:777 - 83.
- Clarke IC, Donaldson TK, Burgett MD, Smith EJ, Bowsher J, Savisaar C, John A, Lazennec JY, McPherson E, Peters CL. Normal and Adverse Wear Patterns Created In-vivo on MOM Surfaces - a retrieval study representing four vendors. In: *Metal-on-Metal Total Hip Replacement Devices*. (Ed. Kurtz SM, Greenwald SA, Mihalko WM, Lemons JA). ASTM International: West Conshohocken, PA; 2013 STP1560; 157-92.
- McHugh D, Currier J, Kennedy F, Collier J, Van Critters D. Plastic Deformation from Edge Loading is common on Retrieved Metal-on-Metal Hips and Can Be Predicted with Finite Element Analysis. In: *Metal-on-Metal Total Hip Replacement Devices*. (Ed. Kurtz SM, Greenwald SA, Mihalko WM, Lemons JA). ASTM International: West Conshohocken, PA; 2013 STP1560; 157-92.
- Heiner A D, Kruger K M, Tikekar N M, Lannutti J J, Callaghan J J, Brown T D. Uncertainty of Head Orientation on the Trunnion Undermines Reliability of Case-Specific Retrieval Wear Simulations. 59th Annual Meeting of the ORS. 2013:Poster No. 1027.
- Bowsher J G, Clarke I C, Williams P A, Donaldson T K. What is a "normal" wear pattern for metal-on-metal hip bearings? *J Biomed Mater Res B Appl Biomater* 2009; 91 (1): 297-308.
- Clarke I C, Lazennec J Y, Brusson A, Savisaar C, Bowsher J G, Burgett M, et al. Risk of Impingement and Third-body Abrasion With 28-mm Metal-on-metal Bearings. *Clin Orthop Relat Res* 2014; 472 (2): 497-508.
- Bergmann G, Deuretzbacher G, Heller M, Graichen F, Rohlmann A, Strauss J, et al. Hip contact forces and gait patterns from routine activities. *J Biomech* 2001; 34 (7): 859-71
- Paul J P. Biomechanics. The biomechanics of the hip-joint and its clinical relevance. *Proc R Soc Med* 1966; 59 (10): 943-8.



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## SCHEDULE

### FRIDAY, OCTOBER 2, 2015

6:00 AM	Breakfast & Registration
7:00 AM	General Session
10:00 AM	Break
10:30 AM	General Session
12:00 PM	Lunch Workshops
1:00 PM	General Session
3:00 PM	Break
3:30 PM	General Session
5:00 PM	Adjourn

### SATURDAY, OCTOBER 3, 2015

6:00 AM	Breakfast & Registration
7:00 AM	General Session
9:45 AM	Break
10:15 AM	General Session
12:00 PM	Lunch Workshops
1:00 PM	General Session
3:00 PM	Break
3:30 PM	General Session
5:30 PM	Adjourn

### SUNDAY, OCTOBER 4, 2015

6:00 AM	Breakfast & Registration
7:00 AM	General Session
10:00 AM	Break
10:30 AM	General Session
1:30 PM	Adjourn



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## Excessive Anteversion Leads to Failure at 3 Years Due to Impingement as Evidenced by Twin Notches in Ti6A4V Stem

Donaldson T<sup>1</sup>, Burgett-Moreno M<sup>1</sup>, Clarke I<sup>1</sup>

### Abstract

A 63-year old female with bilateral hip replacements was referred to our clinic for pain and elevated metal ions. Her left hip had been revised earlier. The right hip had an SROM Ti6Al4V stem implanted with a 28mm head, a 28mm CoCr liner and Pinnacle Ti6Al4V shell. The patient reported pain, numbness, tingling, and repeated clicking and popping sensations with gait. She specifically noted that her hip would freeze while walking and could pop rising from a chair. Repeated metal ion levels showed Co (blood) 17ppb, Cr (serum) 21ppb, and Ti (blood) at 69ppb. CT-images of right hip revealed femoral stem anteversion was 43° and cup anteversion was 40°, for a combined anteversion of 83°. The right hip was revised 3.5 years postoperatively for persistent pain and elevated metal ions. At surgery, large twin notches were evident on her posterior femoral neck and 10mm-wide scalloped damage was evident in the rim of the Ti6Al4V shell. SEM-imaging revealed contaminating layers on CoCr head containing elements Al, V and Ti. These indicated that titanium-alloy particles liberated by cup-to-neck impingements had transferred to the CoCr bearings. Our intent in this case was not to document that a MOM bearing produced impingement damage, because this case clearly implicated adverse surgical positioning. Rather, the intent was to document sequelae likely in a THA case that has a metal cup impinging on a metal femoral neck. In particular, twin notches on the femoral neck indicated that this patient was routinely impinging her Ti6Al4V shell against the Ti6Al4V neck and also subluxing her femoral head out of the cup. These signs are a clear indication that one or both components must be revised, as opposed to simply replacing the CoCr liner with a revision polyethylene liner.

**Keywords:** S-ROM, metal-on-metal, impingement, notches, total hip

**Level of Evidence:** AAOS Therapeutic Level IV

### Introduction

Impingement in 28mm THA may be a common pathway to failure [1-7]. In support, metal-on-polyethylene (MPE) bearings have shown impingement damage in 45-65% of cases [3, 8-10]. Likewise, a recent retrieval study of ceramic-on-ceramic (COC) retrievals noted impinge-

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ment occurred in 83% of 28mm and 32mm COC retrievals [11] and a recent metal-on-metal retrieval study indicated that 96% of large-diameter metal-on-metal (MOM) retrievals showed evidence of impingement [12]. One of the sequelae to routine impingement of a total hip arthroplasty (THA) can be rim damage to the acetabular cup and notching damage of the femoral neck [19-22]. If carried over hundreds of thousands of gait cycles as a result of repetitive sub-clinical subluxation (RSS) [13-15], considerable damage can result. The fact that COC and MOM retrievals showed such consistent impingement damage is not by itself proof that such led to revision. Nevertheless, such evidence may indicate why some 28mm MOM cases showed good results over 7-15 years and others showed lesser success [16-18].

### Consent

The patient signed an IRB approved consent allowing review of her records and analysis of her hardware as well as verbally consented to publication of her case.

## Case Report

A 63 year old female with bilateral hip replacements was referred to our clinic 3 years after her right primary THA for pain and elevated metal ions. An S-ROM femoral stem had been implanted with a 28mm S-ROM femoral head and 28mm Pinnacle cup (Depuy, Warsaw, IN). The patient reported pain, numbness, tingling, and repeated clicking and popping sensations with ambulation. She specifically noted that the hip would freeze up during strides while walking and pop when rising from a chair. Additionally, the referring physician reported metal ion concentrations (blood) with Co and Cr ion levels of 6.4ppb and 38.9ppb, respectively. Metal ion levels were repeated and Co (blood) was 16.7ppb, Cr (serum) was 21.4ppb, and Ti (blood) was 69ppb. Radiographic analysis at 3 years demonstrated normal bilateral hip replacements with S-ROM stems (Figure 1). It was noted that the left hip was a metal-on-polyethylene with significant anteversion, and therefore, was revised first. CT images of the right hip confirmed that both the femoral stem was 43° anteverted and the acetabular cup was 40° anteverted, giving a combined anteversion of 83°. This resulted in very limited external-rotation and extension of the femoral component.

The right hip was revised 3.5 years postoperatively for persistent pain and elevated metal ions. At surgery, the patient had a significant collection of dark synovial fluid as well as a large amount of black synovial lining throughout the acetabulum, over the greater trochanter, and posterior

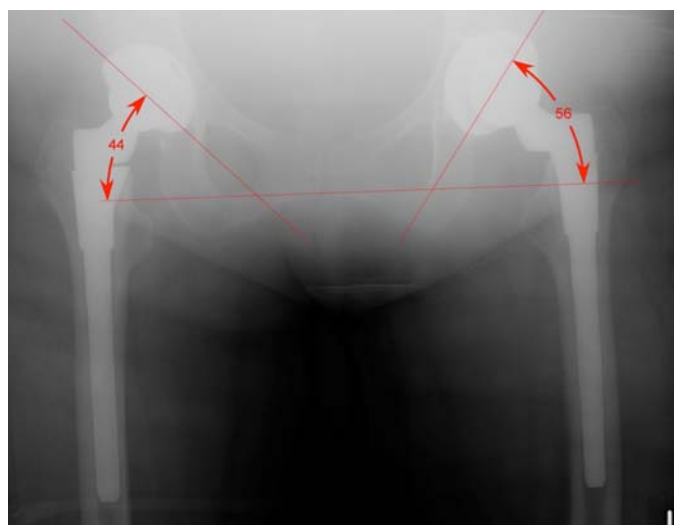


Figure 1: AP Pelvis radiograph with left hip 56° cup inclination and right hip 44° cup inclination.

bursal sack. The large twin notches were clearly evident on the posterior femoral neck during surgery.

### Retrieval Analysis

The retrieved components were cleaned using a standard, non-destructive process, then inspected visually and by stereomicroscopy to define the main wear zone areas (MWZ), cup rim breakout wear, and stripe damage [12].

Twin notches were observed on the femoral stem with the proximal notch and distal notch measuring 4.5mm and 2.5mm wide, respectively (Figure 2a). SEM imaging showed a raised peak between the two notches as well as a slight variation in measured width of the notches (Figure 2b). On the cup, a cosmetic blemish was noted on the CoCr

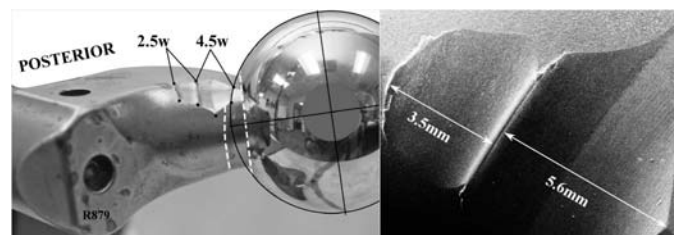


Figure 2: a) Photograph of S-ROM® stem with twin notches on posterior side of stem b) SEM image of twin notches.

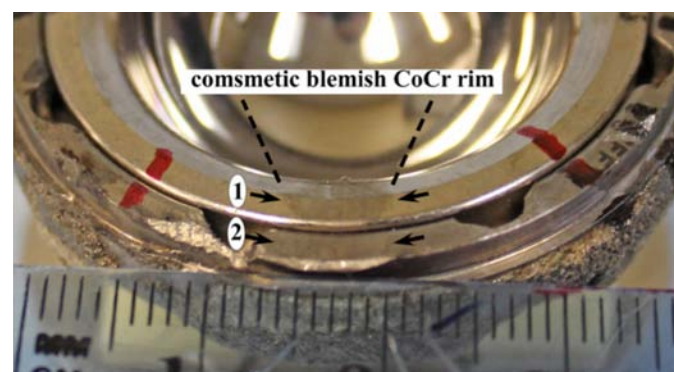


Figure 3: Photograph of (1) cosmetic blemish of the CoCr liner rim and (2) scallop in Ti6Al4V shell rim, evidence of impingement with the femoral neck.

rim and more conspicuously a 10mm long deformity in the rim of the Ti6Al4V shell was identified (Figure 3). SEM imaging (EVO MA15, Zeiss) of the Ti6Al4V shell rim revealed a scalloped portion of the rim bevel (Figure 4).

Suspecting cup rim impingement, the contours of the CoCr liner and Ti6Al4V shell rims were replicated using a silicon agent (Aquasil-LVTM, Densply, Milford DE) and analyzed by SEM. The inner and outer cup rims spanned 4.2mm and 3.1mm, respectively (Figure 5). These proved to be a good match with the twin notches on the femoral neck. As detailed by white light interferometry (WLI: NewView600, Zygo Inc) the notches were cut 0.5 to 0.8mm deep in the S-ROM neck (Figure 5). Additionally, SEM imaging of stripe wear on the femoral head revealed contaminating surface layers of metal measuring 2µm thick (Figure 6) and were identified by EDS imaging (Bruker) as containing elements titanium, aluminum, and vanadium, indicative of titanium alloy and most likely the result of repetitive cup-to-neck impingement with release of metal particles.

Both the femoral head and cup presented with virtually circular wear areas. The femoral head had several polar stripes across the superior MWZ and basal stripes outside

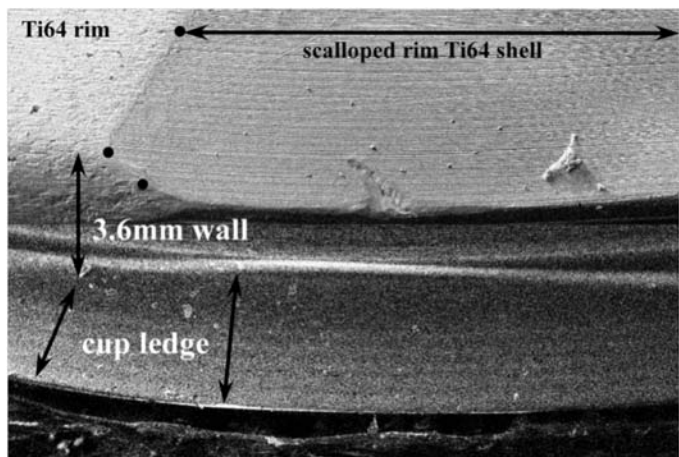


Figure 4: SEM image of scalloped Ti6Al4V shell rim.

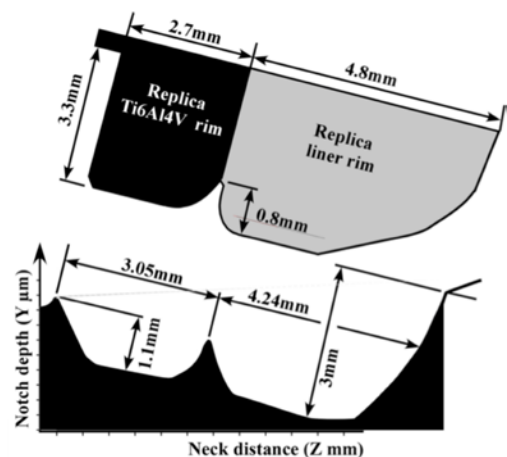


Figure 5: Replicated rims of Pinnacle Ti6Al4V shell and Ultamet CoCr liner represented a good match to the twin notches on the S-ROM femoral neck.

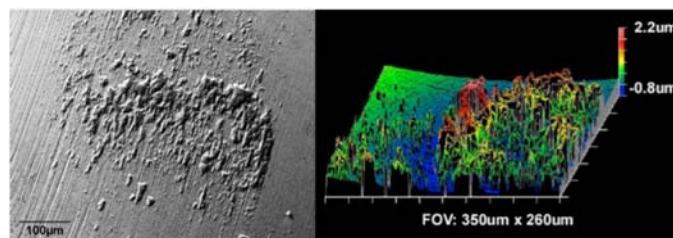


Figure 6: a) SEM image of titanium transfer onto CoCr head b) WLI image of titanium transfer on CoCr head measuring 2µm.

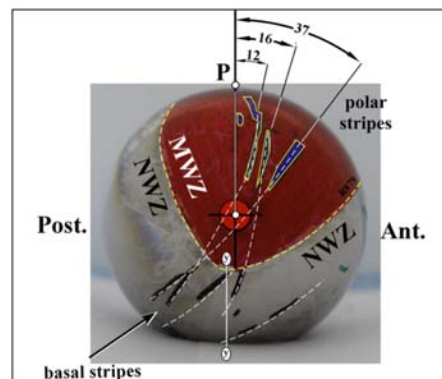


Figure 7: CoCr femoral head with polar stripes and basal stripes demarcated and measured according to the polar axis (P).

the MWZ. Polar stripe angles were measured with reference to the polar axis (P) and revealed an approximate 20° variance between points of impingement (Figure 7).

## Discussion

The intent of this study was not to document that a MOM bearing can produce impingement damage, because this case clearly implicated adverse surgical positioning. Rather, the intent was to document sequelae likely in any THA case that has a metal cup impinging on a metal femoral neck (Table 1).

ID	Damage Evidence	Site	Causation	Involvement	Sequellae
1	Twin notches	Neck	impingement	liner + shell	Ti6Al4V, CoCr particles
2	Twin defects	Cup	impingement	liner + shell	Ti6Al4V, CoCr particles
3	Main wear zone	Head	asymmetric	restricted in extension	Modified gait pattern
4	Metal transfer	Head	metal debris	Contaminated bearing	Ti6Al4V debris
5	Polar stripes, head	Head	terminal motion	head, liner	CoCr particles
6	Basal stripes	Head	terminal motion	head, liner	CoCr particles
7	Multiple notches, stripes	Head	Subluxation	Head levered out of cup	Cup edge-wear

Table 1. Consequences due to CoCr liner and Ti6Al4V shell impingement against Ti6Al4V femoral neck.



Neck-notching case reports are relatively few even in 28mm THA [2, 5, 19-21, 23]. Impingement in this case did little damage to the CoCr liner, produced a fairly mild scalloping in the Ti6Al4V shell rim, but did produce major wear damage to the Ti6Al4V femoral neck. Impingement against a titanium alloy implant is known to produce more damage than with a CoCr implant [23], resulting in release of large particles of titanium alloy known to create adverse MOM wear [24, 25]. The positioning of polar stripes and the evidence of twin neck notches was further indication that not only was impingement present, but the femoral head was subluxing out of the cup (Table 1). We have documented this in other case reports and shown that head subluxation produces edge-wear in the cup rim [12, 22-23]. The damaged rim of the Ti6Al4V acetabular shell was recessed approximately 0.1mm below the face of the Ultamet CoCr liner. This highlighted the fact that the femoral neck impinged first on the rim of the CoCr liner. Thus, once the head subluxed 10° out of the cup, the Ti6Al4V neck was able to pivot and wear on the rim of the Ti6Al4V shell. Our priority in this case was to revise a 28mm MOM bearing to a ceramic-on-polyethylene construct. In consequence, this patient experienced multiple dislocation problems and two more revisions. Thus twin notches on the femoral neck may be considered a clear indication of head-subluxation and dislocation risk with attendant adverse wear conditions, indicating a need to revise one or both components.

It is our opinion that impingement is commonplace, unpredictable, and impossible to guard against. Commonplace examples are the blackened surfaces on ceramic balls, typically containing Ti, Al and V elements representing contamination by Ti6Al4V particulates (Figure 8). If the stem is revised with the MOM bearing there can be evidence of circumferential damage created by cup impingement, typically cosmetic blemishes on CoCr necks but actual notching in Ti6Al4V necks. On the femoral head there will most likely be evidence of polar stripe damage created by the cup rim at the terminal positions of various functional activities.

## References

1. R.L. Barrack, T.P. Schmalzried, Impingement and rim wear associated with early osteolysis after a total hip replacement : a case report, *J Bone Joint Surg Am*, 84-A (2002) 1218-1220.
2. D. Gambera, S. Carta, E. Crainz, M. Fortina, P. Maniscalco, P. Ferrata, Metallosis due to impingement between the socket and the femoral head in a total hip prosthesis. A case report, *Acta Biomed Ateneo Parmense*, 73 (2002) 85-91.
3. M. Yamaguchi, T. Akisue, T.W. Bauer, Y. Hashimoto, The spatial location of impingement in total hip arthroplasty, *J Arthroplasty*, 15 (2000) 305-313.

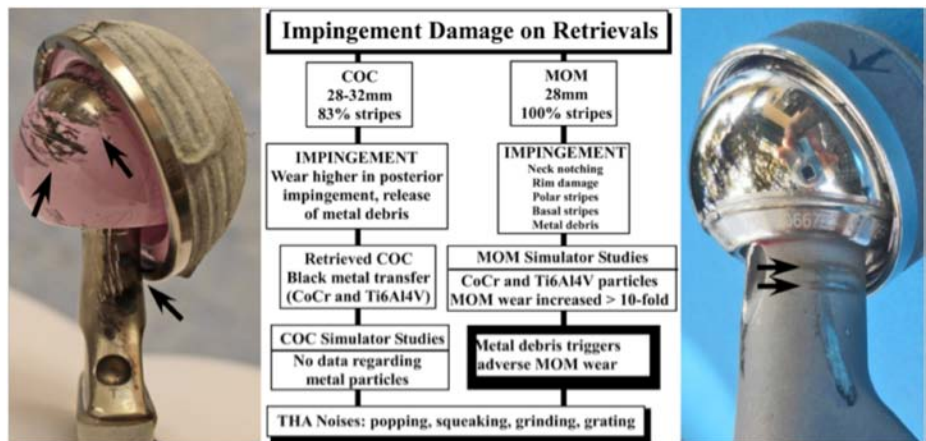


Figure 8: Consequences due to CoCr liners and Ti6Al4V shells impinging against either CoCr or Ti6Al4V femoral necks. Circumferential marks of impingement can be notches in Ti6Al4V necks and cosmetic blemishes in CoCr necks (arrows).

4. M. Earl, T. Fehring, W.L. Griffin, J.B. Mason, T.H. McCoy, Early osteolysis associated with trunion-liner impingement, *Clin Orthop*, (2004) 153-156.
5. K. Onda, S. Nagoya, M. Kaya, T. Yamashita, Cup-neck impingement due to the malposition of the implant as a possible mechanism for metallosis in metal-on-metal total hip arthroplasty, *Orthopedics*, 31 (2008) 396.
6. M. Manaka, I.C. Clarke, A. Gustafson, A. Imakiire, Impingement in Ceramic Hip Patient: A retrieval and Wear-Scar Analysis of Femoral Head., *Key Eng. Mater.*, 240-242 (2003) 847-848.
7. F. Randelli, L. Banci, A. D'Anna, O. Visentin, G. Randelli, Cementless Metasul metal-on-metal total hip arthroplasties at 13 years, *Journal of Arthroplasty*, 27 (2012) 186 - 192.
8. M. Kligman, B.D. Furman, D.E. Padgett, T.M. Wright, Impingement contributes to backside wear and screw-metallic shell fretting in modular acetabular cups, *J Arthroplasty*, 22 (2007) 258-264.
9. W.Y. Shon, T. Baldini, M.G. Peterson, T.M. Wright, E.A. Salvati, Impingement in total hip arthroplasty a study of retrieved acetabular components, *J Arthroplasty*, 20 (2005) 427-435.
10. R.M. Hall, P. Siney, A. Unsworth, B.M. Wroblewski, Prevalence of impingement in explanted Charnley acetabular components, *J Orthop Sci*, 3 (1998) 204-208.
11. C.I. Esposito, W.L. Walter, A. Roques, M.A. Tuke, B.A. Zicat, W.R. Walsh, W.K. Walter, Wear in alumina-on-alumina ceramic bearings. A retrieval analysis of edge loading, *J Bone Joint Surg Am*, 7 (2012) 901-907.
12. I.C. Clarke, T.K. Donaldson, M.D. Burgett, E.J. Smith, J. Bowsher, C. Savisaar, A. John, J.Y. Lazennec, E. McPherson, C.L. Peters, Normal and Adverse Wear Patterns Created In-vivo on MOM Surfaces - a retrieval study representing four vendors, in: S.M. Kurtz, S.A. Greenwald, W.M. Mihalko, J.A. Lemons (Eds.) *ASTM Symposium on Metal-on-Metal Total Hip Replacement Devices*, ASTM International, West Conshohocken, PA, 2013 pp. 157-192.
13. E.J. McPherson, I.C. Clarke, T.K. Donaldson, M.D. Burgett, A MOM dislocator case demonstrating importance of impingement damage in triggering adverse 3rd-body abrasive wear risks, in: *Orthopedics Today*, Jan 13 - 16, Hawaii, 2013.
14. E.J. McPherson, I.C. Clarke, T.K. Donaldson, Lesson learned from retrieval analysis of a dislocating, large diameter MoM revision THA - A case report, *Reconstructive Review*, 2 (2012) 10 - 14.
15. E. McPherson, C. Peters, Correction of Femoral Acetabular Impingement at the Time of Primary Large Diameter Metal-Metal THA, in: *AAOS New Orleans, LA*, 2010.
16. K. Bjorgul, W.N. Novicoff, S.T. Andersen, O.R. Ahlund, A. Bunes, M. Wiig, K. Brevig, High rate of revision and a high incidence of radiolucent lines around Metasul metal-on-metal total hip replacements, *Bone Joint J*, 95-B (2013).
17. V. Eswaramoorthy, P. Moonot, Y. Kalairajah, L.C. Biant, R.E. Field, The Metasul metal-on-metal articulation in primary total hip replacement: clinical and radiological results at ten years, *J Bone Joint Surg Br*, 90 (2008) 1278-1283.
18. J.Y. Lazennec, P. Boyer, J. Poupon, M.A. Rousseau, C. Roy, P. Ravaud, Y. Catonne, Outcome and serum ion determination up to 11 years after implantation of a cemented metal-on-metal hip prosthesis, *Acta Orthop*, 80 (2009) 168-173.
19. H. Iida, E. Kaneda, H. Takada, K. Uchida, K. Kawanabe, T. Nakamura, Metallosis due to impingement between the socket and the femoral neck in a metal-on-metal bearing total hip prosthesis. A case report, *J Bone Joint Surg Am*, 81 (1999) 400-403.
20. A. McMurtre, R. Abhijit, A.R. Guha, J.R. Wootton, Loose Metasul liner causing partial amputation of the neck of the femoral component, *Journal of Arthroplasty*, 24 (2009) 159.e151 - 153.
21. A. Malik, L.D. Dorr, W.T. Long, Impingement as a mechanism of dissociation of a metasul metal-on-metal liner, *J Arthroplasty*, 24 (2009) 323.e313-326.
22. T.H. Eickmann, I.C. Clarke, A. Gustafson, Squeaking in a ceramic on ceramic total hip, in: H. Zippel, M. Dietrich (Eds.) *Bioceramics in Joint Arthroplasty*, Steinkopff Verlag, Darmstadt, Berlin, Germany, 2003, pp. 187 - 192.
23. Clarke I C, Lazennec J Y, Brussen A, Savisaar C, Bowsher J G, Burgett M, et al. Risk of Impingement and Third-body Abrasion With 28-mm Metal-on-metal Bearings. *Clin Orthop Relat Res* 2014; 472 (2): 497-508.
24. Halim T, Burgett M, Donaldson TK, et al. Profiling the third-body wear damage produced in CoCr surfaces by bone cement, CoCr, and Ti6Al4V debris: a 10-cycle metal-on-metal simulator test. *Proc Inst Mech Eng H* 2014;228:703-713.
25. Halim T, Clarke I C, Burgett-Moreno M, Donaldson T, Savisaar C, Bowsher J. A simulator study of adverse wear with metal and cement debris contamination in metal-on-metal hip bearings. *Bone Joint Res* 2015;4:29-37.



## Metallic Modular Taper Junctions in Total Hip Arthroplasty

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### Abstract

The emergence of modularity in total hip arthroplasty (THA) in the 1980s and 1990s was based on the fact that the benefit of these design features outweighed the risk. The use of metallic modular junctions presents a unique set of advantages and problems for use in THA. The advantages include improvement in fit and fill of the implant to bone, restoration of joint mechanics, reduced complications in revision surgery and reduction of costly inventory. However, the risks or concerns are a little harder to identify and deal with. Certainly corrosion, and fatigue failure are the two most prevalent concerns but now the specifics of fretting wear and corrosive wear increasing particulate debris and the potential biological response is having an impact on the design and potential longevity of the reconstructed hip. Material and designs are facing a shorter life expectancy than what was previously thought, mostly due to an increasing level of physical activity by the patient. Because there are no accurate laboratory test whereby the service life and performance of these implants can be predicted, early controlled clinical evaluations are necessary. Early publication of testing and clinical impressions should be encouraged in an attempt to reduce exposure to potential at risk patients, implants and material. The reduction and possible elimination of risks will require a balancing of all the variables requiring a multidisciplinary endeavor.

This paper is designed to review the risk factors, and benefits of modular junctions in total hip arthroplasty (THA). Also some basic engineering principals that can reduce risk factors and improve functionality of modular junctions.

**Keywords:** hip, arthroplasty, debris, fretting, modularity, taper, metal ions, and metallurgy

**Level of Evidence:** AAOS Therapeutic Level III

### Introduction

In dealing with the vast and complex problems associated with reconstructive total hip arthroplasty (THA), one of our tools is the use of metallic modular junctions. [1,2,3,4] Recently there has been considerable discussion and debate surrounding the risk benefit ratio is using modularity. [5,6,7] Modularity selected for THA is typically determined by ascertaining the intended function of the modular junction in the overall reconstruction of the hip. The most

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suitable modular designs are those that are well tolerated by the body and can withstand increased cyclic loading in an ever-demanding environment, especially with the physical activities and expectations of today's patients. Often, the totality of factors that must be assessed when choosing a modular junction for implantation is not completely considered. Typically, the surgeon considers only one issue, which is material strength. Other critical factors of modularity selection include corrosion resistance, cost, and ability to manufacture. [3,6,8]

Individual modular design parameters can offer significant advantages for both fit and fill of implant to bony structures while providing more options for intraoperative customization of joint mechanics and significant economic value in reducing levels of finished goods inventory (Figure 1). [6,9] Now, amid reports of clinical incidents in which metal modular junctions have demonstrated fretting, corrosion, and pseudotumors, there is renewed interest as to what causes these junctions to fail. [9,10,11,12,13] The recent fall in the use of modularity can be contributed primarily to concerns with inflammatory reactions to metal debris. Can failures be predicted or avoided? When a failure does occur what can be done about it?



Figure 1. Example of various modular junctions. (Courtesy of JISRF)

## Current Concerns with Metallic Materials

Implant compatibility and particulate debris in THA is not a new concern and has been an issue of debate since the first attempt to replace a hip joint in the 1890s. One of our greatest allies in reconstruction is the use of metals for implant fabrication; however, this requires an understanding of the biological and engineering principles involved. [8,14]

While modular designs represent an advance in the ability to precisely fit the implant to the bone and restore joint mechanics, the mechanical integrity of the assembled component must be fully tested before clinical use. Fabrication methods, tolerances, surface characteristics, materials, electrochemical environment and mechanical environment are all critical factors that need careful consideration in evaluating the long-term performance of modular interfaces. In evaluating the mechanical performance of modular femoral stems, there is no single test that can adequately represent the various conditions that a hip stem may be subjected to in vivo.

Biocompatibility is mainly determined by the implant surface properties. When a metal implant comes in contact with biological tissue, the following occurs:

1. The implant is first covered with proteins from the body fluids, then cells may attach according to the implant surface properties.

2. The body will either tolerate a biocompatible implant or a foreign body reaction will occur. For metals, this depends on the surface properties of the implant, such as surface chemistry and roughness. Proteins and cells interact differently on surfaces with different properties (Figure 2). If the implant is biocompatible, the inflammation will decrease. If the implant is not biocompatible, a chronic inflammation can occur with possible consequence of a foreign body reaction. In addition, damaged surfaces may evolve to release ions that are potentially allergenic/toxic. This is the beginning of the corrosion process (Figure 3,4,5).

It seems that every 10 years, concern regarding problems from implanted materials resurface. It has been almost four decades since Willert first described the problem of polyethylene wear leading to peri-prosthetic inflammation, granuloma, bone resorption, and implant loosening. [15] Bobyn et al presented an AAOS scientific exhibit in 1993 reviewing problems and solutions with particulate debris in THA. [10] This review covered concerns with

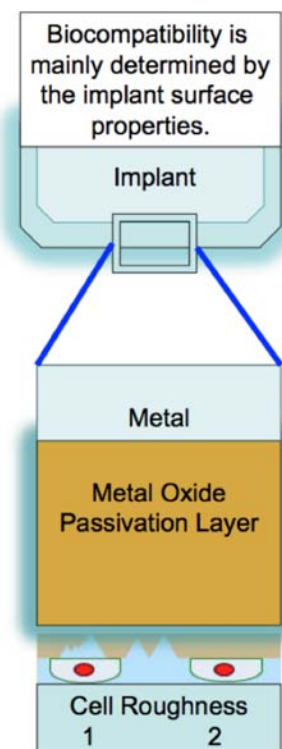


Figure 2. Chart showing the Biocompatibility of Metallic Implants. Cell one is strongly attached because the surface is rougher than cell two attached to a smooth surface.



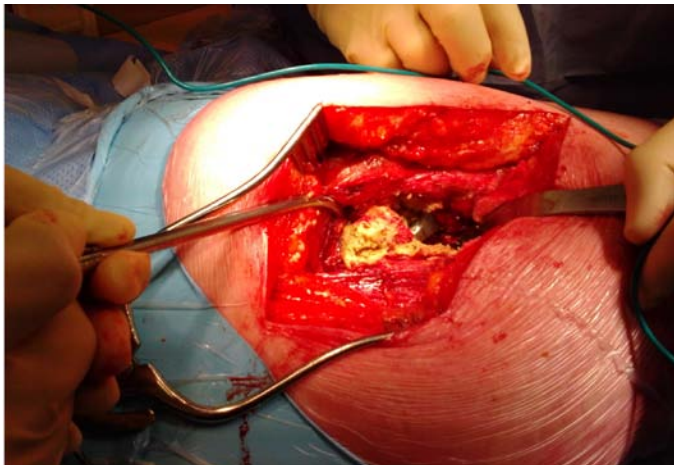


Figure 3. Extensive necrosis as a result of Adverse Reaction to Metal Debris. (Courtesy of E. Smith)



Figure 5. Capsular tension and wear slurry aspiration in a patient with ARMD. (Courtesy of E. Smith)

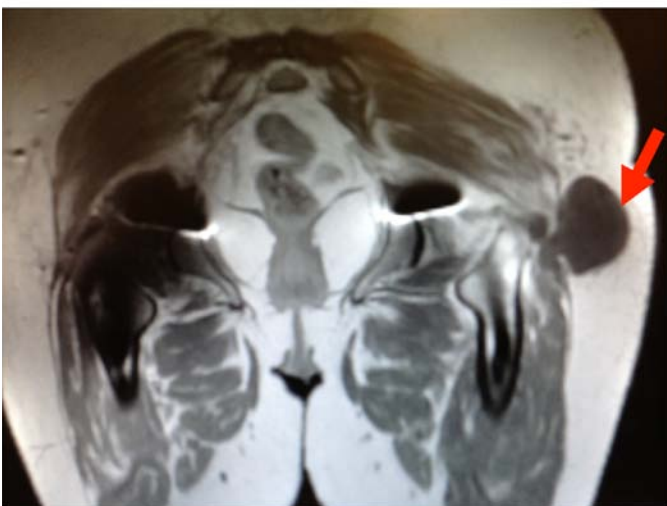


Figure 4. Examples of magnetic resonance images of a pseudotumor (arrow) adjacent to a metal-on-metal hip prosthesis / Adverse Reaction to Metal Debris (ARMD) (Courtesy of E. Smith)

modularity (tapers, dovetails, pads, and stem segments) in both the femoral and acetabular component. So what is different today? Why the increased concern?

Material selection and fabrication has not been altered

to any great degree since the 1990s. However, three significant factors have come into play. First, volume of total joint surgery has increased (U.S.), and primary THA is projected to increase by 174% to 572,000 per year by 2030. [16] Second, THA is being done on younger patients and patient activity overall within all age groups has increased. Third, small design alterations may have significant negative outcomes. [7,8,9,10,13]

Another possible factor is the reluctance of surgeons to provide postoperative precautions with regard to early physical activities. Regardless of material or design, the surgical process for preparing and inserting a total hip stem requires a fracture healing response of the bone. Bone remodeling initially occurs under the stable condition of fracture with rigid fixation and no gap formation—the key being stability of implant to bone to maintain the biological healing response. [17] Modular junctions are designed to work in a stable environment. If the implant has instability and micro-motion, it is very likely the modular junction will encounter increased stress that can lead to a breakdown of the stability of the modular junction, which results in fretting and or corrosion.

Recent concerns with modular tapers can be attributed to the results with metal-on-metal (M-o-M) hip resurfacing (HR) and by extension, the use of large heads (greater than 36 mm) in THA. [18] Small diameter heads (28-32 mm) have had favorable results since the late 1980s. [19,20,21] However, the market demand to reduce dislocations in THA pushed the M-o-M bearings into larger head diameters. While it took time to see the problems with large M-o-M heads, it is also possible that the signs were overlooked. Since 1956, there have been reports of soft tissue tumors caused by metallic alloys. [22] By 1998, Jacobs reported that the taper junction between head and stem was responsible for the significant increase in titanium and cobalt concentrations in the patient, even when the prostheses were

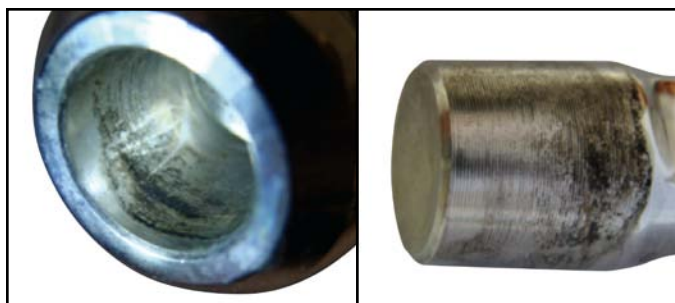


Figure 6. Fretting abrasion wear and corrosion on a head (Co-Cr-Mo) head & stem trunnion taper (Ti-alloy).

functioning well [23] (Figure 6). In the 2010 National Joint Registries of England and Wales (NJR), problems were becoming obvious with the focus being directed to the taper junction. [24] In 2012, the Medicines and Healthcare products Regulatory Agency (MHRA) in the United King-

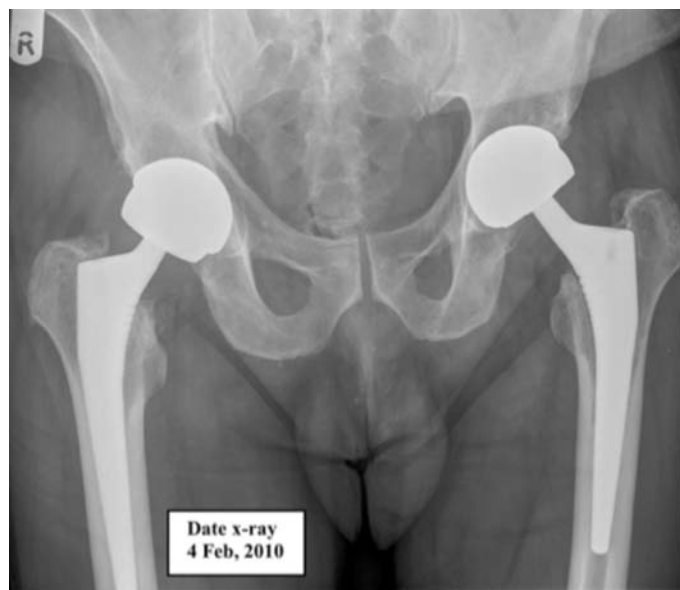


Figure 7a. AP-pelvic view of bilateral ASR THA, strongly suggestive of proximal osteolysis. (Courtesy of Mr. A. John MB BS, FRCS, FRCS, University Hospital of Wales)



Figure 7b. Lateral view of right stem with ASR M-o-M bearing clearly demonstrating progressive proximal osteolysis. (Courtesy of Mr. A. John MB BS, FRCS, FRCS, University Hospital of Wales)

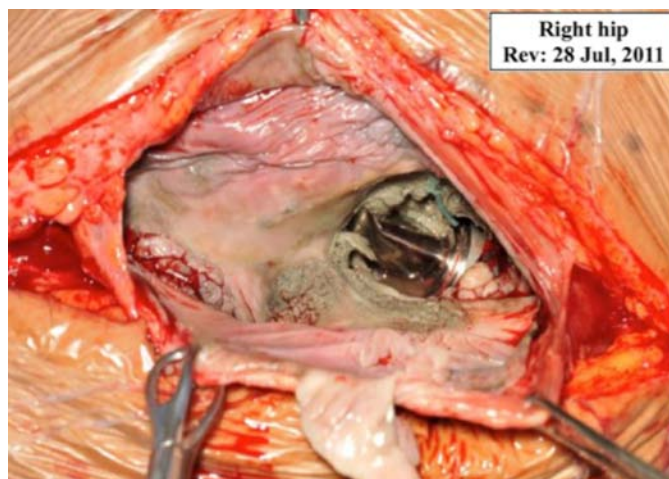


Figure 7c. Initial view of femoral neck and head at revision surgery following removal of extensive pool of green-yellow fluid. (Courtesy of Mr. A. John MB BS, FRCS, FRCS, University Hospital of Wales)

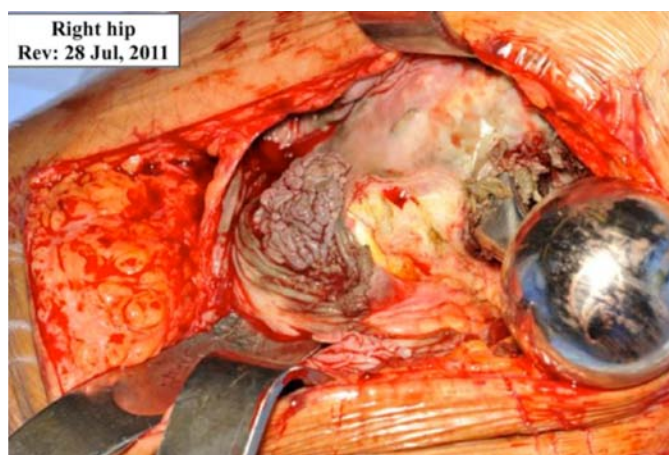


Figure 7d. Extraction of head revealing mass of necrotic tissue around proximal femur. (Courtesy of Mr. A. John MB BS, FRCS, FRCS, University Hospital of Wales)

dom (UK) issued new guidelines on larger head (+36mm) forms of “M-o-M” hip implants. Patients with a large M-o-M hip implant should have annual health checks for life as compared to previous recommendation of up to five years. (Figure 7a, 7b, 7c, 7d).

In May 2015, Michael Morlock published a review paper on tapers showing examples of head/neck taper fractures with a Ti-alloy stem taper and a titanium sleeve connector to the femoral head [25] (Figure 8). He further



Figure 8. Illustration Showing a Ti-alloy taper sleeve



pointed out in his paper that the European Union with the establishment of a Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) working group investigating “The safety of M-o-M joint replacements with a particular focus on hip implants about the M-o-M problems.”

The preliminary consensus of this working group was published in September 2014 and addressed this topic explicitly: “This metal debris can originate either from the bearing articulation directly or from the modular taper junction between prosthesis head and stem. In the past, the taper has only been reported anecdotally as the origin of problems. Recently, the taper has emerged as the focus of attention, since large modular metal heads for M-o-M arthroplasty were introduced due to their ability to reduce dislocation risk, which is the second major complication in hip arthroplasty. These larger heads, however, put larger loads on the taper junction and are suspected to be responsible for the problems suddenly occurring at this side.” [21,26]

The success of a self-locking taper is influenced by the design of the taper, particularly the taper angle, the roughness, and the mating materials between the “male” and “female” components. (Figure 9a, 9b) This results in co-integration (locking), with material transfer across the zone of contact (cold welds). The degree of fit (interference) is determined by the rel-

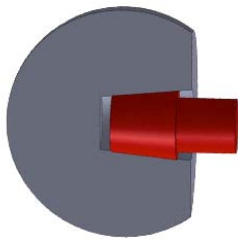


Figure 9a. Schematic of head/neck taper.

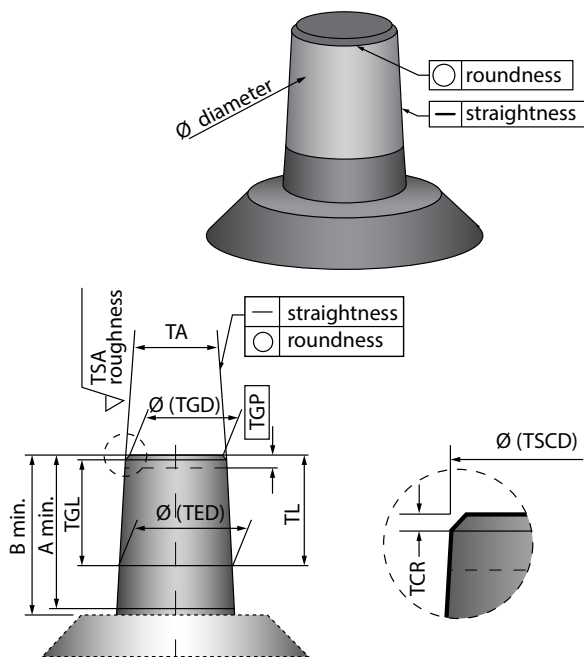


Figure 9b. Characteristics of a head/neck taper. (Redrawn from CeramTec Source by Chris Burgess) [28]

ative dimensions of the two components (male and female regions), and a design decision to have interference along a specific part of the taper’s circumference and length. The area of interference contact must be adequate to maintain integrity under functional (loaded) conditions, while the surface finish of the components must be specific to the physical and mechanical properties of each component’s material. [17,34]

In the last two decades, manufactures have been altering femoral stem trunnions from various tapers such as 14/16 to 12/14 to 11/13 (Figure 10). The Ceramtec 12/14



Figure 10. Illustration Showing Different Taper Designs by Manufactures. (Courtesy of Chris Burgess, Signature Orthopaedics Ltd.)

taper at one time has been referred to by most in Europe as a European 12/14 taper. This term was not trademarked, and some companies began altering the manufacturing tolerance as originally produced from Ceramtec. The term “Euro taper” still is used by most in Europe to describe an off-the-shelf 12/14 Ceramtec taper. [27,28]

A range of different Morse taper angles, component tolerances and sizes, and surface finishes exist within commercially available hip systems. While manufacturers do not recommend mixing and matching of component brands, a number of surgeons have been mixing and matching without complications, provided the products used have the same manufacturing tolerances. [29] A survey published in 2005 from the New Zealand Orthopaedic Association showed that 23% of the surgeons had implanted mismatched components within the last five years [36] (Figure 11).

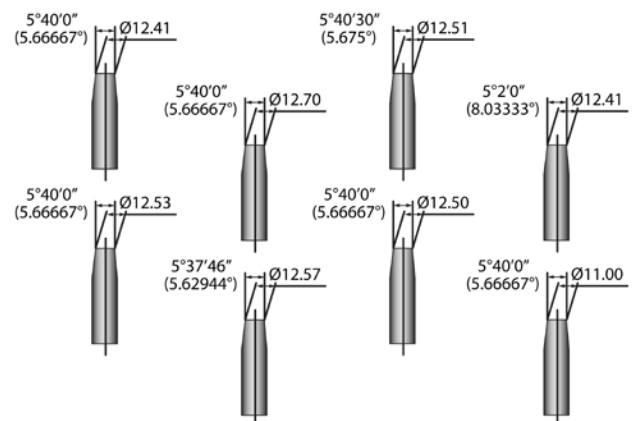


Figure 11. Various designated “12/14” Tapers (Redrawn from CeramTec Source by Chris Burgess) [28]

Amid rising concerns of modular junctions, it is important to remember most hip implant revisions are not the cause of modularity. Aseptic loosening, osteolysis/wear, instability/dislocation, infection and periprosthetic fracture remain as the major reasons for hip revision surgery. One



Figure 12a. Detachment of modular head can damage stem trunnion. (Courtesy of J. Keggi)

reason for revision that is growing in frequency is the failure of large M-o-M bearings. [30]

It is important to remember that early introduction of stem modularity did present problems, including disassociation of modular heads, incorrect head diameters implanted, and trunnion fatigue fractures [31] (Figure 12a, 12b). Unique to modular head/neck designs is the

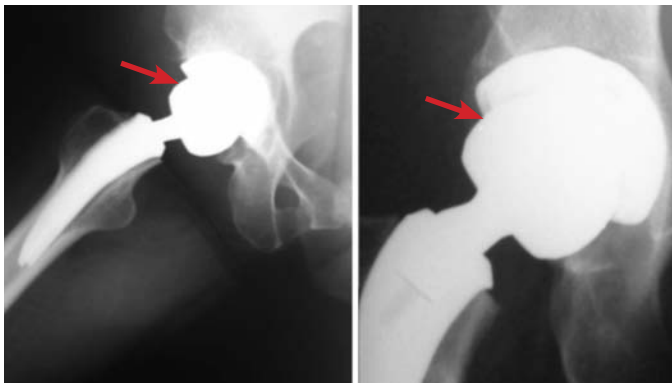


Figure 12b. Post-op X-Rays demonstrating mismatch between modular head and modular cup liner. (36mm head-32mm liner). The advantage here is this stem has a modular neck so a simple exchange replacing neck (new trunnion) and head to match poly liner. (Courtesy of JISRF)

risk of dissociation of the head in association with dislocation and attempts at closed reduction. [43] This can often leave a well-fixed stem in place with some degree of damage to the stem trunnion. This may be an indication to use a modular trunnion sleeve to engage with the modular head, especially if you intend to use a ceramic head (Figure 13). Multimodularity in stem designs, along with the use of larger head diameters, brings with it serious concerns with regard to corrosion and its biological reaction to increased metal ions and particulate debris.



Figure 13. Modular ceramic head with a Ti-alloy sleeve inserted into the femoral head is helpful when stem trunnion is damaged. (Courtesy of JISRF)

## Corrosion

Corrosion of metals has many different mechanisms that all have independent driving forces. Corrosion can be defined as the degradation of a material due to a reaction with its environment. There are many forms of corrosion and no universally accepted terminology is in use. The following terminology is based on current use by NASA-Kennedy Space Center. [32]

### Galvanic corrosion

Galvanic corrosion is an electrochemical action of two dissimilar metals in the presence of an electrolyte and an electron conductive path. It occurs when dissimilar metals are in contact.

Worldwide ISO standards recognize the detrimental effect of galvanic corrosion cells that can be established in the body, and this should be considered during implant design. [8] When reduced taper length is combined with larger femoral heads, the outcome has been that industry experiences a new failure mode in THA “trunnionosis.” [33] One factor that can drive the trunnionosis phenomena is the use of different materials at modular junctions. Fundamental science states that two different materials in a conducting media will generate a battery or corrosion cell. Consequently, all differing materials mated together in the human body will set up a corrosion cell to some extent. The extent on the corrosion cell is affected by the fluid conductivity and galvanic potential difference between the two materials. [8]

### Pitting corrosion

Pitting corrosion is localized corrosion that occurs at microscopic defects on a metal surface. The pits are often found underneath surface deposits caused by corrosion product accumulation.

### Crevice corrosion

Crevice or contact corrosion is the corrosion produced at the region of contact of metals with metals or metals with nonmetals.

### Stress corrosion

Stress corrosion cracking is caused by the simultaneous effects of tensile stress and a specific corrosive environment. Stresses may be due to applied loads, residual stresses from the manufacturing process, or a combination of both.

### Corrosion fatigue

Corrosion fatigue is a special case of stress corrosion

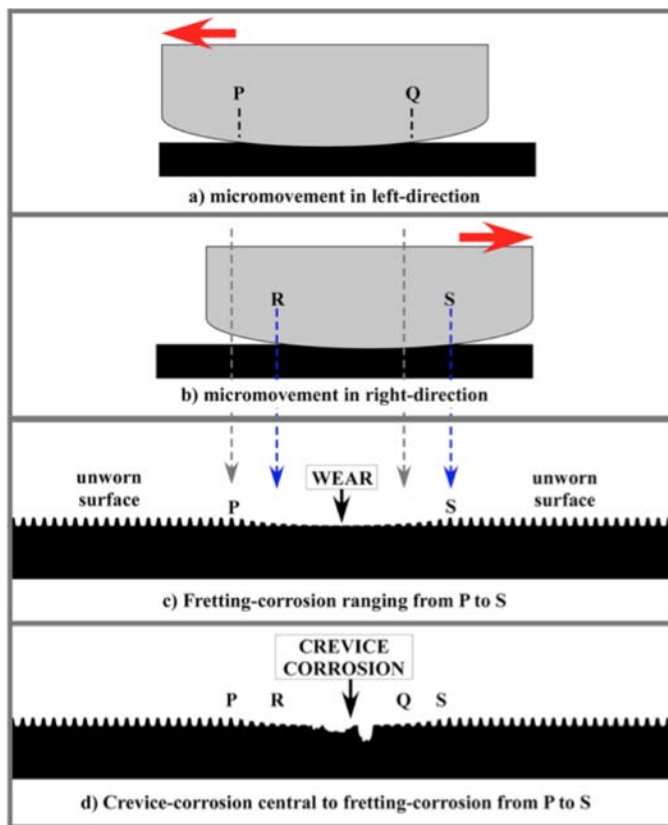


Figure 14a. Schematic illustrating that oscillatory motions as small as 10-100µm can induce wear and mechanically-assisted crevice corrosion (MACC). Such relative motion is unavoidable because modular junctions inherently introduce parts of different rigidity (size, shape) and different alloys (stiffness criteria). (Courtesy of Ian Clarke)

caused by the combined effects of cyclic stress and corrosion. No metal is immune from some reduction of its resistance to cyclic stressing if the metal is in a corrosive environment.

### Fretting corrosion

Fretting corrosion is the rapid corrosion that occurs at the interface between contacting, highly loaded metal surfaces when subjected to slight vibratory motions (Figure 14a, 14b).

Using these definitions, one can better understand the mechanisms behind product deterioration among the different THA junctions.

## Challenges with the Neck/Stem Modular Junction

Fretting corrosion has recently been attributed to the decline in the clinical acceptance of modular neck hip implants. It has also been the reason for the recall of two products (Rejuvenate™ and ABGII™) by Stryker Or-

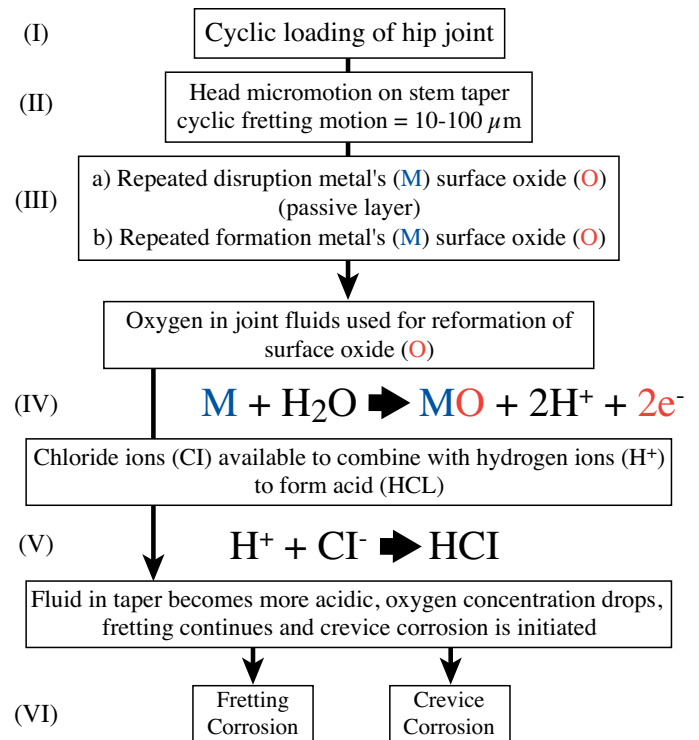


Figure 14b. Electrochemical reactions involved in mechanically-assisted crevice corrosion (MACC: redrawn from data in Gilbert et al, 1997). Cyclic loading is a necessary hip function and the resulting micromotion can disrupt the protective oxide film on metal surfaces. Ideally this will quickly reform, the metal combining with oxygen from the local environment and in the process releasing hydrogen and negatively-charged electrons. Under adverse conditions, the fretting continues, the oxygen concentration is depleted, and the formation of a protective oxide layer is compromised. In addition the surrounding environment is becoming more acidic as the hydrogen ions recombine with chlorine ions to form hydrochloric acid, thereby promoting dissolution of the metal surface. (Gilbert et al 1997) (Courtesy of Ian Clarke)

thopaedics, Mahwah, NJ. [7,8,34,35,36] A main driving mechanism behind fretting corrosion is stress, or load. Increasing the stress at the modular junction will proportionally increase the extent of the fretting corrosion (Figure 15). Reviewing the design of the modular junction of these products indicates that the application of some fundamental engineering principles could have reduced the probability of fretting corrosion. Figure 16a and 16b shows the length of taper support versus the offset of the modular neck for the Stryker, Wright Medical, and TSI/ ARC™ systems. The recalled products from Stryker have reduced taper support (13 mm versus 15, and 17 mm) with increased bending and torsional moments (Figure 16c), which produces much higher stresses at the modular junction and



Figure 15. Retrieval of taper corrosion with dissimilar metals—cobalt-chrome alloy modular neck on titanium Stryker stem. (Courtesy of Dartmouth Biomedical Engineering Center.)





Figure 16a. Showing Modular Necks taper support engagement and percent increase in stress for engagement support.



Figure 16b. Modular Neck/Stem Designs showing neck/stem taper engagement length (Stryker ABG II Modular-13mm, Wright-15 mm, ARC-17mm) (Courtesy of JISRF)

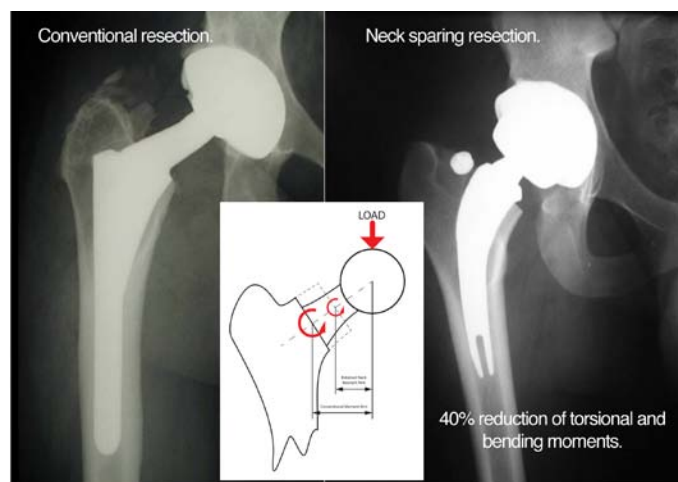


Figure 16c. Two Postoperative X-rays showing different level neck resections and offsets resulting in less bending and torsional moments in the neck-sparing implant. (Courtesy of JISRF)



Figure 16d. Explanted Stryker ABG II Modular Necks Showing Fretting and Corrosion (Courtesy of WL. Walter)

potentially leads to a more rapid fretting corrosion rate as compared with neck preserving style stems (Figure 16d). [7,8] Figure 17 shows results of presentation by Brazil and McTighe on FEA modeling comparing level of neck resection (neck sparing stem versus conventional); as compared with a conventional neck resection, the neck sparing resection results in a 35% reduction in principal tensile stress. [46]

Recent marketing trends have also contributed to problems at the modular junction. The use of large femoral heads (greater than 36 mm) M-o-M bearings, increased femoral offset, increased leg length, and reduced precautions on patient-related physical activity may result in higher stresses at the modular junction. [7,8] These actions

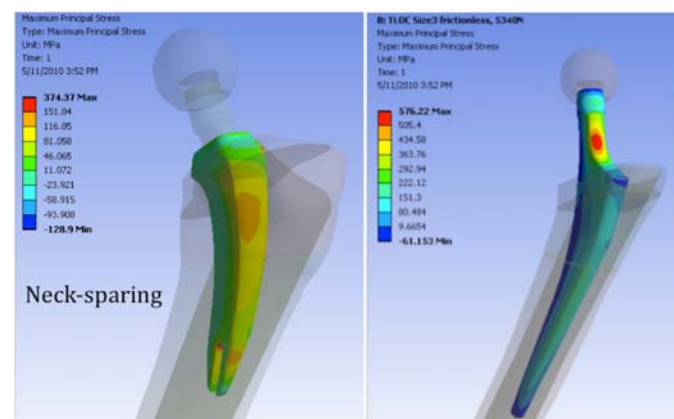


Figure 17. FEA Modeling showing 35% less tensile stress in a neck-sparing resection compared to a conventional neck resection. (Courtesy of D. Brazil)

increase torque moment at the modular implant interface. On average, a 1-mm true lateral increase to the ball center offset will increase torque values by 8%. A 1-mm increase in vertical height (leg length) will increase torque by 6% (Figure 18).

Reduced taper engagement area, along with increased patient body weight and increased physical activity levels, places significant torsional loads on the implant. Torque

►Per 1mm increase in true lateral ball-center offset increases torque by 8%

►Per 1mm increase of ball's neck-length increases torque by 6%

Offset	Neck-Length	Nm
35 mm	49.50	84
40mm	56.58	96
45mm	63.65	108
50 mm	70.72	120
55 mm	77.79	132

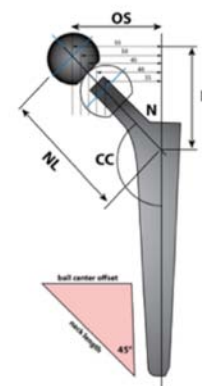
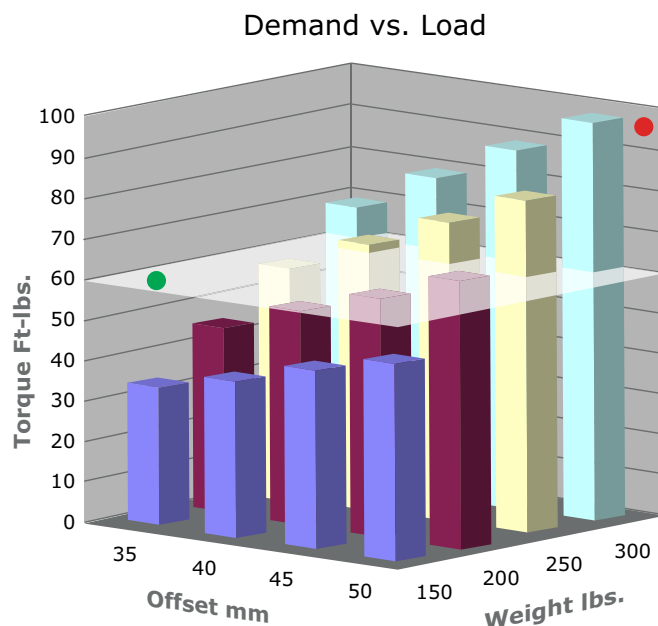


Figure 18. Chart Showing Torsional Loads per offset and neck-length (Courtesy of Ian Clarke)



is a force applied over a distance (lever arm) that causes rotation about a fulcrum (axis of rotation) ( $\text{Torque} = \text{Force (Fm)} \times \text{Moment Arm}$ ). The greater the torque a muscle can produce, the greater the movement it will produce on the body's levers. [45] Example of patient at risk would be an active male weighing 250 lbs with a 50 mm femoral offset, a combination that would generate in excess of 70ft-lbs of torque. Design limit for most tapers is approximately 60 ft-lbs. We know by previous reports that the hip sees torque values over 95 ft-lbs, as demonstrated in some mechanical failures of first generation modular hip stems [13] (Figure 19).



- We know the hip generates loads above 90 ft-lbs.
- Design limit 60 ft-lbs.

Figure 19. Chart Showing Torque Loads Generated by Femoral Offset and Body Weight.

One such torsional failure mode was presented as a poster exhibit at the 2006 ISTA Annual Meeting reporting on a proximal modular neck design that featured a “Dual Press™” modular junction. The Dual Press modular junction employs two areas of cylindrical press-fit (Figure 20). This allows the proximal portion of the shoulder to fully seat, providing medial support, which increases strength and allows higher lateral offsets. The rotation of the proximal body is restricted by a locating pin. The pin strength was established at 95ft-lbs, well above historical published reports on torsion. These modular junction failures were not a fatigue failure mode, and no surgical errors or fabrication defects were found. The culprit appeared to be patient activity resulting in a mechanical overload in a static shear mode failure (perfect storm). The solution was rather



Figure 20. Dual-Press Modular Junction (Omni, East Taunton, MA) Illustration Showing two areas of press fit allowing proximal shoulder to sit flush with stem body.

simple: replace the old pin diameter from .125” to .188” and change the old plug to a new feature of a bolt that engages the stem. This revision resulted in 225% increase in torsional strength. It serves as an example that changes and improvements are possible once there is a full understanding of the problem. There have been no reported mechanical failures of its modular junction since 2004 with the improved design (Figure 21a, 21b, 21c).

Since 2004, there have been more than 7,000 Omni

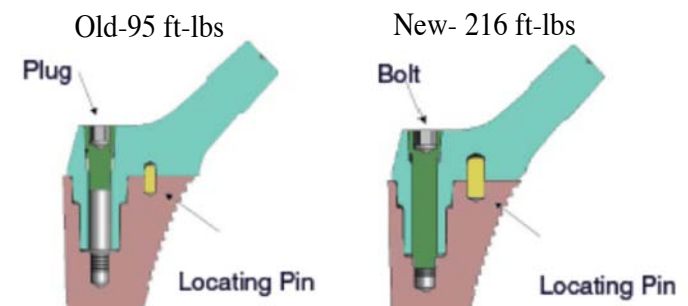


Figure 21a. Illustration showing old Dual-Press design to new improved design increasing torsional resistance from 95 ft-lbs to 216 ft-lbs.



Figure 21b. Explanted Apex Modular Stem (Dual Press Modular Junction, Omni, East Taunton, MA) showing sheared de-rotation pin and fretting abrasion wear. No signs of corrosion. (Courtesy of Keggi)

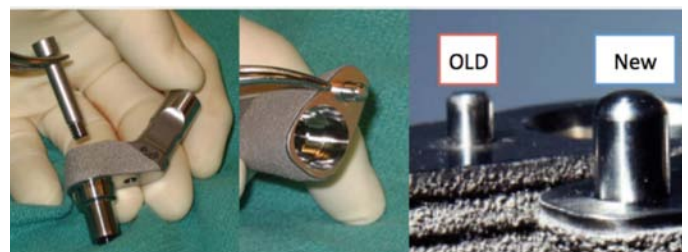


Figure 21c. Picture showing old pin diameter of .125” to new diameter of .188” increase in strength (+225%). (Courtesy of K. Keggi)

MOD II and more than 3,000 Omni K2 Dual Press improved junctions implanted. Seventeen revisions involving the OMNI MOD (.23%) and four involving the OMNI K2 Stems (0.12%) have been reported to OMNI. Of these, two involved increased metal ion levels (as determined by the patient's physician), and in both cases the OMNI MOD Stem was used with another manufacturer's M-o-M femoral head and acetabular cup bearing combination. The revisions involved removing the competitor's head and cup and replacing the OMNI MOD Modular Neck, leaving the stem in place. There have been no other reports of metal ion concerns, corrosion, or fretting with the OMNI MOD and OMNI K2 Modular Stems. [47]

Another example of modular neck failure was the original OTI™ Co-Cr-Mo modular neck that interfaced with a Co-Cr-Mo stem. The failure mode for this device was basic fatigue failure caused by an under-designed modular junction. Improvements made to this novel neck design, which increased surface contact by 40%, included specific size increases of the taper trunnion that improved mechanical strength from 520-700 lbs to greater than 1,200 lbs (Figure 22a and 22b). To our knowledge, there has been no reported failures with the improved modular junction design. [48,49]

Our own research using a short-curved neck sparing modular neck that mates with a Co-Cr-Mo neck with Ti-alloy stem is undergoing extensive fretting and corrosion testing of the additional surface coating of selected regions of the Co-Cr-Mo modular neck with titanium nitride (TiN).



Figure 22a. Pictures showing a fatigue failures in explanted OTI Co-Cr-Mo modular neck and close up of broken neck within the stem cone body. Stem, neck and head are Co-Cr-Mo. (Courtesy of JISRF)

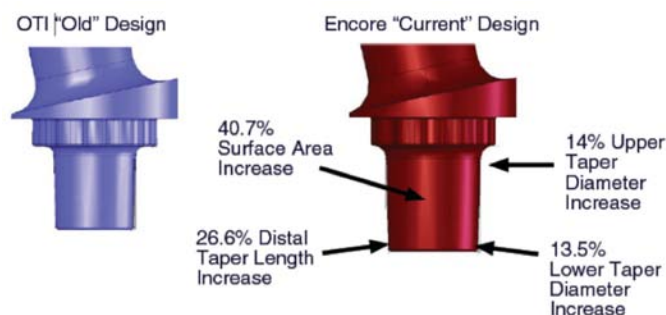


Figure 22b. Illustration showing modular taper improvements from the original OTI™ design to the Encore improvement design. (Courtesy of JISRF)

This material process reduces the potential galvanic reaction between the materials and consequently reduces the probability of corrosion between mating surfaces. This fundamental design concept can be further applied to the internal surfaces of the femoral head that interfaces with a Ti-alloy stem taper. Our initial results have been presented at various CME meetings with very favorable results in reduction of fretting abrasion wear between the TiN distal coated necks versus non coated necks. [7,8,36,37] TiN fully

coated necks saw the

same results for the distal coated necks but saw no difference in the proximal portion interfacing with a Co-Cr-Mo femoral head (Figure 23).

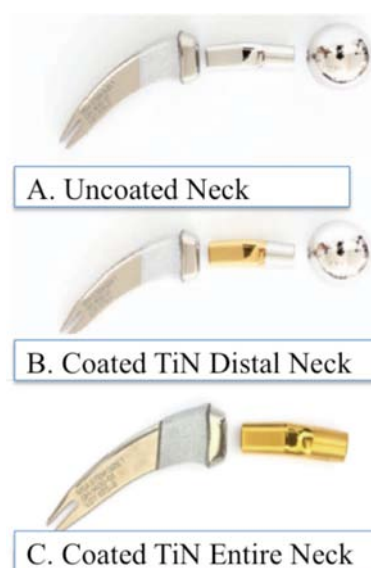


Figure 23. Showing test samples (ISO7206-6 Setup 5340 N-10 Million Cycles Measured Abrasive Wear) comparing TiN coated modular Co-Cr-Mo necks interfacing with Ti-alloy stems.

- The TiN distal coated necks (B) showed significantly less fretting wear when tested under the same load conditions as group A.
- The fully coated necks (C) showed the same results as group (B) for the distal neck and no difference interfacing with Co-Cr-Mo heads.

## Challenges with the Stem/Sleeve Modular Junction

The success of the S-Rom® modular stem system stimulated most companies to rush into the market with a modular style hip. [9,38,39] The S-Rom stem, an evolution of the original Sivash stem, experienced a number of design changes before becoming the novel design that still survives today. Most think the modular features were the single most important factors to its success. In reality, the clinical success can be contributed to its basic geometric design that provided for immediate implant stability with the potential for long-term fixation with a reproducible surgical technique. The modular features are secondary to its basic geometric structure.

Fracture of the S-Rom stem is rare; however, it does happen, and fractures have been reported at different sites in the femoral stem body. Pearce et al reported two stem fractures at the mid-stem junction at the top of the slotted portion of the stem. [40,41,42] One of our authors had a fractured stem (4 years postoperatively) within the sleeve/



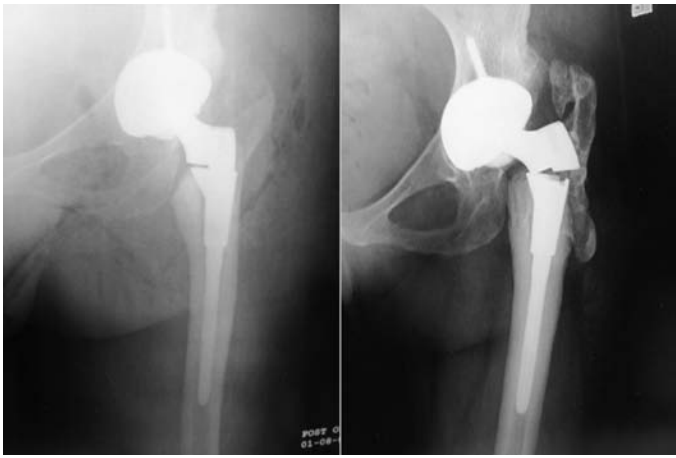


Figure 24. Two postoperative X-Rays showing a S-Rom stem used for a DDH patient that sustained a fracture of the proximal stem within the modular sleeve area. (Courtesy of J. Keggi)

stem junction in a DDH patient that requiring the smallest S-Rom stem (9 mm) (Figure 24). We are also seeing some signs of corrosion at the stem/sleeve junction. Urban et al reported at the 53rd Annual Meeting of the Orthopaedic Research Society on 30 retrieved stems of three different style modular titanium stems (16 S-Rom, 11 ZMR, 3 Mallory-Head); all of the devices had a Co-Cr-Mo head. Corrosion and fretting damage was observed at 20 of the 30 devices. A wide range in the degree of damage, ranging from minimal to severe, was observed in each of the 3 designs examined. Overall, the damage was minimal in 10 stems, mild in 11, moderate in 6, and severe in 3. In two stems, severe corrosion may have contributed to fatigue fracture. [43]

One area of observation is the process of grit-blasting titanium stem surfaces, which leaves a matte or satin finish (Figure 25). Grit surfaces were introduced in the early 1980s for cemented stems, with the belief that the slightly rough surface finish (RA:  $.7\mu\text{m}$ ) would provide improved bonding of the bone cement interface. Results were just the opposite, with higher aseptic loosening occurring in the grit-blasted stems than in polished stems. [44,45] In retrieving roughened Spectron EF stems (Smith and Nephew, Memphis, TN, USA), Gross et al reported the presence of macroscopic metallosis in all hips. The microscopic examination of the femoral pseudomembrane consistently revealed an inflammatory reaction characterized by the presence of multinucleated giant cells and metallic, cement, and poly-



Figure 25. S-Rom® Stem with proximal modular porous sleeve. (Courtesy of JISRF)

ethylene deposits. [44] In 1992, Buly et al reported on 71 cases of titanium wear debris in failed cemented THA. Femoral bone loss in aseptically loose, primary THA was graded as severe in 51%, moderate in 24%, and mild in 20%. Femoral endosteolysis was present in 94%, while acetabular osteolysis was seen in 6%. Histological evaluation of tissues from failed primary arthroplasties revealed polymethyl methacrylate debris in 75% of cases, polyethylene debris in 80%, metal debris in 75%, and chronic inflammatory cells in all cases. [46] One can conclude from past reports and personal observations that rougher surfaces that interface with another rough surface (bone, cement, metal) under micro or macro movement will suffer fretting abrasion wear.

Many manufactures use the bead blasted or matte finish on titanium stems as a cosmetic process to cover or reduce machine marks from the fabrication process. Figure



Figure 26. Explanted S-Rom Stem showing surfaces scarring (metal transfer) on the proximal stem under the modular sleeve and under the shoulder of the stem. This demonstrates micro-movement between the modular junction. (Courtesy of JISRF)

26 shows a retrieved S-Rom stem with surface scarring, demonstrating metallic transfer of particles at the modular stem/sleeve junction. The abrasive wear at titanium surfaces can affect the metal protective oxide (passivation) layer on the surface of the implants and corrosion can be introduced when this (protective) passivation layer is damaged.

The modular taper connection of the stem/sleeve, which allowed intraoperative customization, did not and does not currently provide sufficient rotational stability to withstand the torsional loads brought about by normal cyclic movement.



Figure 27a. 1984 Polished S-Rom 125° Stem with Proximal Modular Sleeve that engaged a de-rotational locking pin in the stem. (Stem Ti-alloy, Ti-alloy Modular Sleeve & Co-Cr-Mo Modular Head. (JMPC, Stanford, CT) (Courtesy of JISRF)

The original S-Rom 125° stem (1984) had a locking pin through the stem that engaged with the proximal sleeve, reducing the risk of stem slippage within the sleeve (Figure 27a and 27b). One additional problem with the 1984 design was a groove that ran down the anterior/posterior



Figure 27b. X-rays of a S-Rom 125° Stem (1984) showing progressive distal osteolysis over a three-year period. (Courtesy C. Engh & JISRF)

portion of the entire length of the stem. In a poster exhibit at the 2006 ISTA annual meeting, one of our coauthors presented an example of progressive distal osteolysis, in which particulate debris migrated down the grooved stem. This helped make the decision of adding distal flutes, eliminating the groove, and eliminating the locking pin. Another concern with regard to the concept of stem/sleeve modularity is the risk of increasing the length beyond the taper engagement contact zone. During the 1980s, one of our coauthors was part of the S-Rom design team; their study group (Cameron, Mallory, Bierbaum, Bobyn, Moreland, Pugh, Greenwald, Noiles and McTighe) reviewed the design and ruled it out because of increased risk of fretting abrasion wear between distal sleeve and stem (Figure 28). Bending moments can be increased, especially with thinner stem diameters.

EMPERION sleeve options

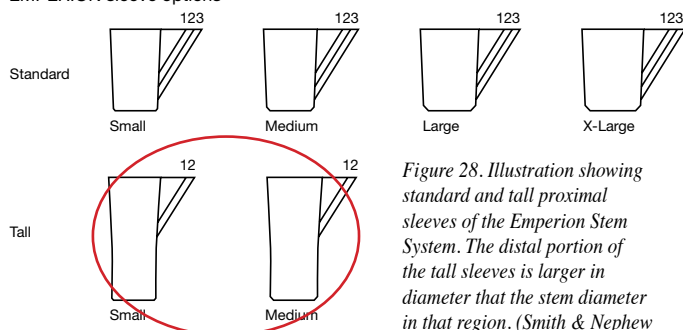


Figure 28. Illustration showing standard and tall proximal sleeves of the Emperion Stem System. The distal portion of the tall sleeves is larger in diameter than the stem diameter in that region. (Smith & Nephew Orthopaedics, Memphis, TN)

## Challenges with Head/Neck Modularity

As taper lengths and taper ratios have changed over the years, standardizing on a 12/14 Euro Ceramtec off-the-

shelf style taper allows for more standard revision options as compared with using a taper neck sleeve adapter. Neck taper adapters may have limitations in design by having skirts that may interfere with range of motion or cause impingement, resulting in generation of particulate debris and or dislocation (Figure 29).



Figure 29. Femoral neck adapters that can convert a smaller taper (11/13 to 12/14) to a larger for revision surgery.

This design concept allows for adjustment of head center vertical height and head center lateral offset. In addition, this feature allows for mixed materials to be selected for the articulation of the bearing surface. The femoral head is commonly fabricated from a Co-Cr-Mo alloy or an alumina-based ceramic. Our research on TiN of Co-Cr-Mo modular necks interfacing with Ti-alloys stems might be carried over to just coating the inside of a Co-Cr-Mo head to reduce potential galvanic reaction of dissimilar materials and reduction of micro-fretting abrasion wear at the head/neck interface. Another improvement already in practice is going back to the concept of a more hemispherical head. This improves the surface contact area for head/neck trunnions that can reduce stress and micro-motion at the interface (Figure 30).

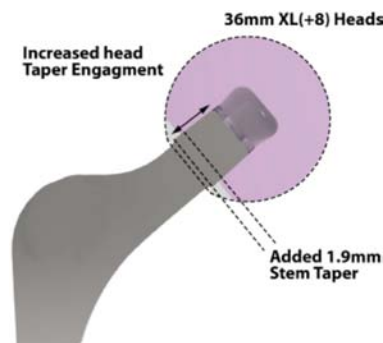


Figure 30. Illustration Showing Increased Surface Contact between Femoral Head and Stem Trunnion by Increasing Contact Length of Taper.

## Summary and Conclusion

The use of metallic modular junctions in hip replacement has increased since the early 1980s, and some might say they are overused. We are seeing an increased num-



ber of complications associated with modularity, including dissociation, corrosion, wear, fretting, and fatigue failure. When modular implants were first introduced, the biggest challenge was the frequent fracture of ceramic heads. Today—more than 40 years after the introduction of modular ceramic heads—fracture is rare, and ceramic modular heads have demonstrated low wear rates, outstanding biocompatibility, diamond-like hardness, and high resistance to third-body wear.

Metallic heads made of titanium alloy proved to be unsatisfactory, increasing wear at the articulation. Metallic heads made from Co-Cr-Mo alloy are strong, and they pose no potential of failure by fracture or fatigue. However, fretting, corrosion, and micro-motion are still major concerns. Modular implants with titanium alloy stems and Co-Cr alloy heads were introduced in order to take advantage of the lower stiffness of Ti alloy for better load transfer to bone while making use of higher wear resistance of Co-Cr alloy heads. The use of these modular implants soon gave rise to corrosion at the modular mating surfaces, which was first thought to be galvanic in nature because the dissimilar materials were involved. Further investigations on Morse taper connections of modular hip prostheses brought about different conclusions on the nature of modular interface failures. Stress, strain, and micromotion at the modular interface can induce fretting abrasion wear, resulting in the generation of particulate debris, increased release of metal ions, corrosion, and adverse tissue (local and systemic) reaction.

Analysis shows that you must carefully consider patient weight and activity level when implanting a hip stem of any design. A 350-pound active male with a 50 mm offset and a 11 mm distal stem exceeds the fundamental fatigue strength of titanium alloy, regardless of proximal stem design or modularity.

Taper issues are the same regardless of where the taper is located (head/neck, neck/stem, mid-stem, or stem/sleeve). Reducing risk associated with tapers can be ameliorated through many strategies; design characteristics such as a large surface contact (length and diameter), stiffer material (less deflection), and tight manufacturing tolerances can reduce stress, strain and micro-motion at the modular junction. This reduces fluid ingress and the extent of fretting that could trigger corrosion by depassivating the protective metallic oxide layers and setting up a crevice corrosion cell. Careful intraoperative techniques for assembly are critical. Both male and female trunnions must be clean and dry before assembly, and proper force must be used to engage the modular junction.

Generation of particulate debris can often be reduced through the careful selection of implant material and fab-

rication. This problem is worse with Ti-based implants because of lower hardness and abrasion resistance. Also, some implant preparation techniques such as bead blasting tend to leave residual contaminants (silica or alumina) that can be dislodged by abrasion at the modular interface. Bead-blasted taper surfaces can produce surface scarring that is material transfer brought on by micro-motion. Taper surfaces should be clean and smooth, then micro-etched with chemical-milling techniques in the fabrication process. Debris can migrate throughout the joint space, accessing any and all implant interfaces. Select designs and material that provide immediate secure fixation that minimize micro-motion, stress, and strain.

The following are some examples of actions to reduce the generation of particulate debris:

- Head/neck tapers: Use 12/14 (Larger and stiffer surface contact area) taper over smaller tapers such as 11/13 or 9/10 when possible.
- Head/neck tapers: Increasing taper length will reduce micro-motion.
- Stem tapers: Many tapers do not have adequate intrinsic stability for high activity, so limit modular junctions or pick designs that have back-up features to support taper junctions (e.g., fluted stems).
- Reduce fatigue failure of modular necks by material choice. Co-Cr-Mo is stronger than Ti-alloy.
- Reduce potential galvanic corrosion of dissimilar metals by TiN coating Co-Cr-Mo necks used with titanium stems.
- Reduce micro-motion, stress, and strain in modular necks by increasing taper engagement.
- Reduce micro-motion, torsional moment, and bending moment on stems (modular necks) by selecting neck sparing stem designs that retain the femoral neck.
- Caution should be used in selection of modular junctions in highly active males that exceeds 250 pounds.

Modular designs have made significant contributions to reconstruction of the diseased and damaged hip—from improving fit and fill of the implants to restoring joint mechanics. While problems have been reported with the use of modularity, the collaborative orthopaedic community (industry, surgeons, and scientists) has been successful in identifying and providing solutions to improve overall designs and outcomes. Modularity can be designed and fabricated to provide safe, reliable, and reproducible clinical results.

As an example of industry stepping up identifying problems and initiating actions from 2002 to 2013, the six largest implant companies have voluntarily recalled 578 hip implants as compared with the FDA using its recall authority three times in 20 years.

It is important to remember all devices are subject to failure. It is also necessary to recognize design and material limits and not to over-indicate in high-risk patients. A number of modular junctions have come and gone from clinical use. Nevertheless, the endeavor to improve clinical outcomes should be continued. Modularity can be designed and fabricated to provide safe, reliable, and reproducible clinical results.

Because there are no laboratory tests allowing accurate prediction of the service life and performance of implant parts, clinical experience with a large number of cases over a period of several years is the only reliable indicator. However, clinical evaluations should only begin after conducting aggressive basic science material and mechanical testing to anticipate potential failure modes. Individual patient physical activities should be considered when deciding on stem modularity features. Since there are no standards established for modular junctions the overall performance of modular junctions are not equal. Careful review of basic engineering principles is necessary and recognizing design limits will reduce the indication of overuse.

To advance scientific knowledge in the long run often requires some short-term setbacks.

### Disclosure Statement:

One or more of our authors have disclosed information that may present potential for conflict of interest with this work. For full disclosures refer to last page of this journal.

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### References

- Cameron H, Trick L, Shepherd B, et al. An international multi-center study on thigh pain in total hip replacements. American Academy of Orthopaedic Surgeons 1991 Scientific Exhibit, New Orleans, Louisiana. DOI: <http://dx.doi.org/10.13140/RG.2.1.2093.2641>
- Mattingly D, McCarthy J, et al. Revising the deficient proximal femur. American Academy of Orthopaedic Surgeons 1991 Scientific Exhibit, Anaheim, CA. DOI: <http://dx.doi.org/10.13140/2.1.3611.7289>
- Keppler L, Cameron H, McTighe T. The Role of Modularity in Primary THA: Is There One? American Academy of Orthopaedic Surgeons 2006 Scientific Exhibit, Chicago, IL. DOI: <http://dx.doi.org/10.13140/RG.2.1.2132.5923>
- Tkach T, Low W, Cipolletti G, McTighe T. Target Restoration of Hip Mechanics in THA. American Academy of Orthopaedic Surgeons 2006 Scientific Exhibit, Chicago, IL. DOI: <http://dx.doi.org/10.13140/RG.2.1.1084.0167>
- Gilbert JL, Buckley CA, Jacobs JJ. In vivo corrosion of modular hip prosthesis components in mixed and similar metal combinations. The effect of crevice, stress, motion, and alloy coupling. J Biomed Mater Res 1993;27:1533-1544.
- Berry DJ. Utility of modular implants in primary total hip arthroplasty. The Journal of Arthroplasty 2014;29:657-658
- McTighe T, Brazil D, Keggi J, Keppler L, et al. Optimizing modular tapers for total hip arthroplasty. <http://www.jisrf.org/pdfs/Optimizing-Modular-Tapers-for-Total-Hip-Arthroplasty-ICJR-July2014.pdf>. Conference Paper July 2014: International Congress for Joint Reconstruction, Pacific Hilton Waikoloa Village Resort.
- McTighe T, Brazil D, Bruce W. Metallic Alloys in Total Hip Arthroplasty. In: Cashman J, Goyal N, Parvizi J, eds. The Hip: Preservation, Replacement and Revision. Baltimore, MD: Data Trace Publishing Company; 2015:14-1-14-12.
- McTighe T. Cementless Modular Stems. JISRF Update, April, 2002 <http://www.jisrf.org/pdfs/cementless-modular-stems.pdf>
- Boby JD, Collier JP, et al., Particulate Debris in Total Hip Arthroplasty: Problems and Solutions. American Academy of Orthopaedic Surgeons 1993 Scientific Exhibit. DOI: <http://dx.doi.org/10.13140/RG.2.1.2355.4080>

- Chana R, Esposito C, Campbell PA, et al. Mixing and matching causing taper wear: corrosion associated with pseudotumour formation. J Bone Joint Surg Br 2012;94:281.
- Cooper HJ. The local effects of metal corrosion in total hip arthroplasty. Orthop Clin N Am 2014;45(1):9.
- Keggi K, Keggi J, Kennon R, et al. Within any important issue, there are always aspects no one wishes to discuss: femoral component failure. Poster Exhibit International Society for Technology in Arthroplasty, October 2006. DOI: <http://dx.doi.org/10.13140/RG.2.1.4779.6329>
- Bechtol CO, Ferguson AB Jr, Laing PG. Metals and Engineering in Bone and Joint Surgery. Baltimore: Williams and Wilkins Company, 1959
- Willert, H.G. and Semlitsch, M.: Reactions of the articular capsule to wear products of artificial joint prostheses. J. Biomed. Mater. Res. 11:157, 1977.
- 16Kutz SM, Ong K, et al., Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. JBJS 89(4):780-5 March 2007 DOI: <http://dx.doi.org/10.2106/JBJS.F.00222> Source: PubMed
- McTighe T, Trick L, Koeneman J. Design Considerations for Cementless Total Hip Arthroplasty. Encyclopedic Handbook of Biomaterials and Bioengineering. Part B Applications Vol I. Marcel Dekker, Inc. 1995 DOI: <http://dx.doi.org/10.13140/RG.2.1.2919.0240>
- Kwon YM, Ostlere SJ, McLardy-Smith P et al. "Asymptomatic" pseudotumors after metal-on-metal hip resurfacing arthroplasty: prevalence and metal ion study. J Arthroplasty. 2011;26 (4):511-8. DOI: <http://dx.doi.org/10.1016/j.arth.2010.05.030>
- Clarke M, Lee P, Aron A, Villar R. Levels of metal ions after small- and large- diameter metal-on-metal hip arthroplasty. J Bone Joint Surg [Br] 2003;85-B:913-7. Received 14 January 2003; Accepted 27 May 2003
- Innman M, Gotterbarm T, et al. Minimum ten-year results of a 28-mm metal-on-metal bearing in cementless total hip arthroplasty in patients fifty years of age and younger. International Orthopaedics May 2014, Volume 38, Issue 5, pp 929-934
- Migaud H, Berton C, et al. Head Size and Metal-on-Metal Bearings. Total Hip Arthroplasty 2013, pp 125-140, Springer Berlin Heidelberg 10.1007/978-3-642-35653-7\_12
- McDougall A. Malignant tumour at site of bone plating. J Bone Joint Surg Br. 1956;38(3):709-713.
- Jacobs JJ, Gilbert JL, Urban RM. Corrosion of metal orthopaedic implants. J Bone Joint Surg Am. 1998;80(2):268-282
- National Joint Registry. 7th Annual Report for England and Wales. 2010. [www.njrreports.org.uk](http://www.njrreports.org.uk); [www.njrcentre.org.uk](http://www.njrcentre.org.uk)
- Morlock M. The taper disaster: How could it happen? Hip Int 2015;May 20(00):000-000 DOI: <http://dx.doi.org/10.5301/hipint.5000269>
- Langton DJ, Jameson SS, Joyce TJ, Hallab NJ, Natsu S, Nargol AV. Early failure of metal-on-metal bearings in hip resurfacing and large-diameter total hip replacement: A consequence of excess wear. J Bone Joint Surg Br. 2010;92(1):38-46.
- Hernigou P, Queinnee S, Lachaniette C. One hundred and fifty years of history of the Morse taper: from Stephen A. Morse in 1864 to complications related to modularity in hip arthroplasty. International Orthopaedics 2013;37:2081-2088 DOI: <http://dx.doi.org/10.1007/s00264-013-1927-0>
- Scheuber L, Usbeck S, Petkow F. The Neck Taper in Hip Arthroplasty-What does the surgeon have to consider? CeramTec Publication, CeraNews 1/2014
- Keggi K, Keggi J, Kennon R, McTighe T. Ceramic on Ceramic Bearings Used with Proximal Modular Stems in THA. Bioceramics in Joint Arthroplasty/Ceramics in Orthopaedics 2004:3-8 DOI: <http://dx.doi.org/10.13140/RG.2.1.3403.9846>
- Langton et al. Accelerating failure rate of the ASR total hip replacement. J Bone Joint Surg [Br] 2011;93-B:1011-16
- Barrack R, Burke D, et al. Complications Related to Modularity of Total Hip Components. J Bone Joint Surg [Br] 1993; 75-B:688-92
- NASA Corrosion Technology Laboratory. Forms of Corrosion. Available [http://corrosion.ksc.nasa.gov/corr\\_forms.htm](http://corrosion.ksc.nasa.gov/corr_forms.htm)
- Pastides P, Dodd M, Sarraf K, Willis-Owen C. Trunnionosis: A pain in the neck. World J Orthop 2013 Oct 18;4(4):161-166 DOI: <http://dx.doi.org/10.5312/wjo.v4.i4.161>
- Modular Neck Stem Voluntary Recall Information. Available at <http://www.aboutstryker.com/modularneckstems/>
- Pivec R, Meneghini M, Hozack W, et al. Modular Taper Junction Corrosion and failure: How to Approach a Recalled Total Hip Arthroplasty Implant. J Arthroplasty. 2014;29(1):1-6.
- McTighe T, Brazil D, Keggi J, Keppler L, et al. Short-Stem Designs for Total Hip Arthroplasty: Neck Stabilized Femoral Components. In Callaghan J, Beaulé P, Clohisy J, et al. The Adult Hip. 3rd ed. Philadelphia: Wolters Kluwer Health, in press.
- Brazil D, McTighe T. Taper Issues in Total Hip Arthroplasty. Oral Paper, 2014 International Congress for Joint Reconstruction, CME Meeting, Sydney, Australia. DOI: <http://dx.doi.org/10.13140/2.1.1748.2889>
- Keppler L, Cameron HU, McTighe T. The role of modularity in primary THA: Is there one? AAOS 2006 Scientific Exhibit, Chicago, IL <http://www.jisrf.org/pdfs/modularity-primary-tha.pdf>. J Arthroplasty 2006; 21(4 Suppl 1):89-92.
- Design features and early clinical Results with a modular proximally fixed low bending stiffness uncemented total hip replacement. AAOS 1998 Scientific Exhibit, Atlanta, GA. DOI: <http://dx.doi.org/10.13140/RG.2.1.4714.7040>
- Pearce S, Jenabzadeh A, Walter W, et al. Spontaneous fracture of diaphyseal stem of S-ROM femoral prosthesis. BMJ Case Reports 2014; DOI:<http://dx.doi.org/10.1136/bcr-2013-202813>
- Waly F, Abduljabbar FH, Gascoyne T, et al. Stem-sleeve junction failure of a modular hip system: a retrieval analysis. HSS Journal Case Report. DOI: <http://dx.doi.org/10.1007/s1420-015-9455-7>. Published online July 9, 2015.
- Patel A, Bliss J, Calfee RP, et al. Modular femoral-sleeve junction failure after primary total hip arthroplasty. J Arthroplasty. 2009;24(7):1143. E1-5. DOI: <http://dx.doi.org/10.1016/j.arth.2008.09.006>
- Urban RM, Gilbert JL, Jacobs J. Corrosion and corrosion products generated by three designs of cementless hip stems with a ti-alloy/ti-alloy modular-body junction. 53rd Annual Meeting of the Orthopaedic Research Society, Paper No: 0277.
- Grose A, Gonzalez A, Bullough P, et al. High failure rate of a modern, proximally roughened, cemented stem for total hip arthroplasty. Int Orthop. 2006;30(4):243-247.
- Collis DK, Mohler CG. Comparison of clinical outcomes in total hip arthroplasty using rough and polished cemented stems with essentially the same geometry. J Bone Joint Surg Am 2002;84-A:586-592.
- Buly RL, Hou MH, Salvati E, et al. Titanium wear debris in failed cemented total hip arthroplasty. An analysis of 71 cases. J Arthroplasty. 1992;7(3):315-23.



## Short-Stem Hip Arthroplasty as a Solution for Limited Proximal Femoral Bone Stock

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*Keywords: Total hip arthroplasty, Short stem prosthesis*

*Level of Evidence: AAOS Therapeutic Level IV*

### Introduction

Achieving stable fixation in total hip arthroplasty (THA) in the presence of limited proximal femoral bone stock is a frequent challenge in the revision setting but less common for primary hip arthroplasty. We describe an uncommon scenario in which options for femoral fixation of a primary hip arthroplasty were limited as the femoral diaphysis was almost completely filled by a long stemmed revision knee replacement.

Conventional hip arthroplasty components have historically used stems greater than 150mm [5]. Several companies have introduced shorter versions of a conventional stem design with lengths less than 150mm [1]. These are popular in Asian races of short stature who often have a narrow femoral diaphysis and curved femurs that conflict with traditional length stems. Hip resurfacing and metaphyseal stems that do not enter the diaphysis, are design alternatives to conventional stems. Metaphyseal stems are short curved designs that preserve some of the calcar femoralis and attempt to load the proximal femur in a more physiological manner [3,12]. Short stems and resurfacing implants have an occasional indication for treating hip joint pathology associated with femoral deformity such as after femur malunion or osteotomy [14]. The described case highlights the conflict of insufficient diaphysis available for hip implant fixation.

lateral hip pain. She had significant co-morbidities which included rheumatoid arthritis, steroid induced osteoporosis, and diabetes. Her Charnley grading was C. She had bilateral primary total knee arthroplasty three years prior to presentation. One year following her primary knee arthroplasties, she sustained bilateral distal femoral fractures after a fall that were managed by revision knee arthroplasties. Her left knee revision had a long stemmed condylar femoral prosthesis while the right was revised with a very long stemmed condylar femoral prosthesis that ended 10cm from the lesser trochanter. This was combined with a strut allograft.

At presentation she was able to ambulate minimally with a frame. Her presenting problem was incapacitating bilateral trochanteric and groin pain, with deteriorating weight-bearing capability and rest pain. Physical examination showed a frail patient with a crouched stance and a support-dependant stiff-hip antalgic gait. Both hips had audible crepitus on movement, fixed flexion deformities with limited flexion and no rotation. Her right knee had a range of motion of 35 – 80 degrees and her left knee 35 – 85 degrees. Her initial radiographs showed bilateral cemented revision knee arthroplasties that filled most of the femoral diaphyses. There was also severe generalised osteopenia

### Case Presentation

A 63 year old female presented with incapacitating bi-

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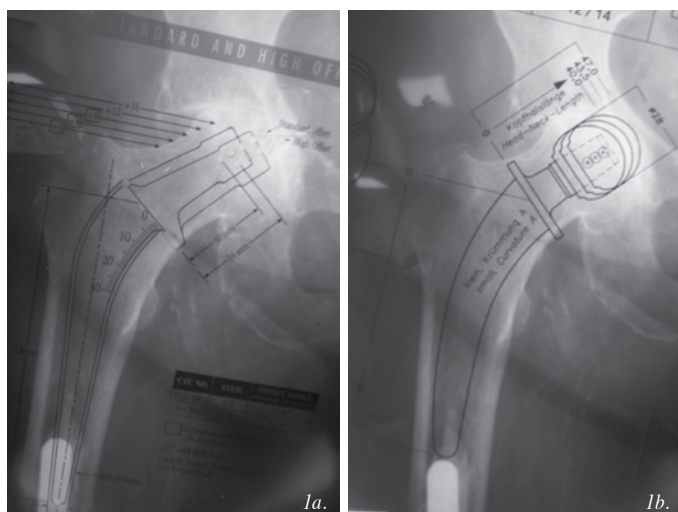


Figure 1: Radiographs showing limited proximal bone on the right.  
 1a. Preoperative templating with a stem of conventional length overlying a long-stemmed revision knee component.  
 1b. Preoperative templating with a short stem femoral prosthesis

with rheumatoid changes in both hips including protrusio acetabuli and complete chondral space loss.

Preoperative templating showed that a prosthesis of traditional stem length could not be accommodated due to the stemmed knee component (Figure 1) and therefore a shorter-neck-preserving implant was selected.

The patient underwent a right total hip arthroplasty using a posterior approach. A LINK® TOP cementless acetabular cup and CFP® (Collum Femoris Preserving) short stem were used (Waldemar Link GmbH & CO, Hamburg, Germany) with intentional lengthening of 15mm to restore her pre-morbid length. Six weeks postoperatively she had a marked improvement in right hip function with no pain, and an improved range of motion. She had persisting difficulty in ambulating due to the left hip pain and stiffness. The left hip was then replaced three months following her right hip surgery with the same implant type and sizes. No post-operative complications were observed.

At one year she reported an improvement in her quality of life and was observed to be ambulating faster with a frame in a more erect position. At five years and eleven years post-surgery she was very content with her hips, and also felt that she had improved knee motion which was attributed to the resolution of the pre-operative hip flexion deformities that had induced her crouched posture. Serial radiographs at one year, five years and eleven years demonstrated stable implants (Figure 2).

## Discussion

The femoral component of a total hip replacement (THR) serves an essential role in transmitting the forces

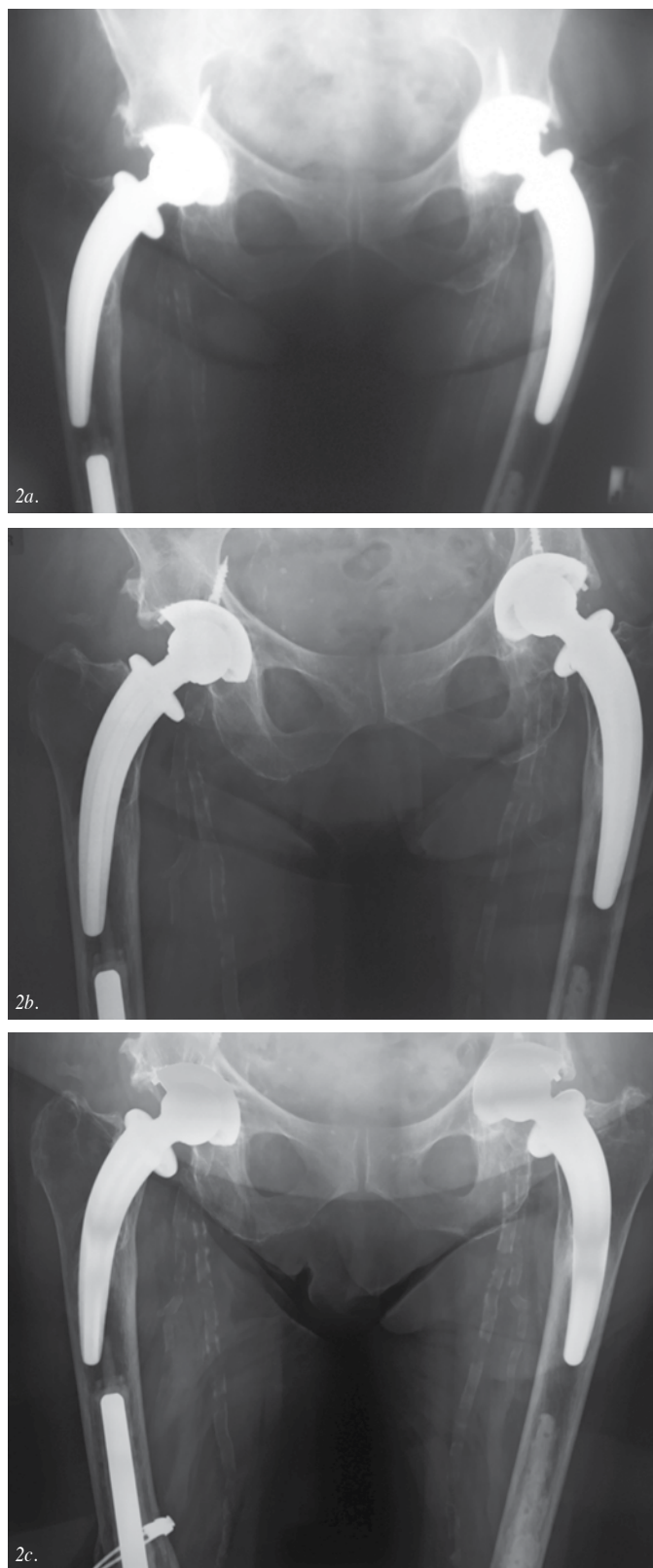


Figure 2: Bilateral total hip arthroplasties with uncemented short stem prostheses proximal to long stemmed revision knee components. Calcar resorption and proximal diaphyseal hypertrophy progresses to eleven years post surgery.  
 2a. One year post Operative.  
 2b. 5 years post operative.  
 2c. Eleven years post operative.



generated at the centre of rotation to the proximal femur. The femoral component historically has a segment that engaged the femoral diaphysis and a variety of lengths have been used [6,8,17,18]. Short stems were initially designed to achieve a more anatomical pattern of stress distribution by loading the femur proximally. Short stems claim several potential advantages which include reducing proximal stress shielding and bone resorption as well as thigh pain, [7] eliminating femoral proximal-distal mismatch, soft and hard tissue preservation, enhanced proximal bone remodeling, less blood loss, shortened postoperative rehabilitation and recovery, minimized instrumentation, fewer inventory costs and simplified femoral revisions. [4,9,13]

A number of classification systems for the short stem have been proposed [3,6,11] mostly based on the stem length, intended site of primary stability, and level of osteotomy. The JISRF [9,10] classification of stems includes four categories; 1) Head stabilized 2) Neck stabilized 3) Metaphyseal stabilized and 4) Conventional (Metaphyseal/Diaphyseal) stabilized. The LINK® CFP (Collum Femoris Preserving) prosthesis is a type 2 or “neck stabilized” short stem. It is an uncemented short stem prosthesis that preserves the femoral neck and proximal cancellous bone. It was primarily developed for biologically young and active patients. Pipino et al, who developed the CFP short stem, reported excellent (82%) clinical mid-term results [15]. At 25 years [16] he reported 97% ‘good’ clinico-radiographic outcomes and a survival rate of almost 100%. He proposed that preserving “healthy” tissue, which includes the femoral neck, has the advantage of maintaining the osteoarticular architecture that would maximize mechanical stability and optimize distribution of mechanical loads, which will then favour enhanced osteointegration and bone remodelling.

This patient was neither young nor active, and had osteoporosis which are all relative contra-indications for a neck preserving short stem prosthesis. The decision to use a short stemmed implant in this patient was a controversial decision made after consideration of her limited and high risk options. She had undergone previous bilateral revision knee arthroplasties and the long stems of her femoral components had consumed most of the femoral diaphysis. This case emphasizes the importance of pre-operative templating which clearly showed that the use of a stem of conventional length was not possible. The alternate surgical option was to also revise her functioning long-stemmed knee components, which could even lead on to total femoral replacements. Acknowledging the relative contraindications associated with her suboptimal bone quality it was elected to proceed with a less invasive surgical option and use a short stemmed press-fit device.

## Conclusion

This case emphasizes the importance of preoperative templating as an important part of pre-operative planning [2]. Confronted with limited high risk options, this case also demonstrates the successful use of a short-stemmed device to permit hip arthroplasty in the presence of inadequate femoral bone stock as a consequence of previous surgery or deformity.

## Disclosure Statement:

The authors of this article have declared there is no potential for conflict of interest and no benefits or funds were received in support of this paper. For full disclosures refer to last page of this journal.

## References

1. Briem D, Schneider M, Bogner N, Botha N, Gebauer M, Gehrke T, Schwantes B. Midterm Results of 155 patients treated with a collum femoris preserving (CFP) short stem prosthesis. *International Orthopaedics (SICOT)* (2011) 35:655-660
2. Egli S, Pisan M, Muller ME. The Value of preoperative planning for Total hip arthroplasty. *J Bone Joint Surg Br* 1998; 80 (3); 382-390
3. Feyen H, Shimmmin AJ. Is the length of the femoral component important in primary total hip replacement? *Bone Joint J* 2014;96-B:442-8
4. Goosen JHM, Van Hellemond G. Primary THA with a retained intramedullary femoral nail. *Acta Orthop Belg*, 2013, 79: 114-116
5. Keisu KS, Orozco F, McCallum JD III, Bisset G, Hozack W, Sharkey P, Rothman R. Cementless femoral fixation in the Rheumatoid Patient undergoing Total Hip Arthroplasty: Minimum 5 year results. *The Journal of Arthroplasty* Vol.16 No.4 2001
6. Khanuja HS, Banerjee S, Jain D, Pivec R, Mont MA. Short Bone-Conserving Stems in Cementless Hip Arthroplasty. *J Bone Joint Sur Am* 2014 Oct15;96 (20);1742-1752
7. Kim YH, Kim JS, Cho SH. Strain distribution in the proximal human femur: An in vitro comparison in the intact femur and after insertion of reference and experimental femoral stems. *J Bone Joint Surg (Br)* 2001;83-B:295-301
8. Kim YH, Park JW, Kim JS. Is Diaphyseal stem fixation necessary for primary total hip arthroplasty in patients with osteoporotic bone (Class C bone)? *The Journal of Arthroplasty* Vol. 28 No.1 January 2013
9. McTighe T, Stulberg SD, Keppler L, Keggi J, Kennon RT, Brazil D, Aram T, McPherson E, & TSITM Study Group Members. Joint Implant Surgery & Research Foundation (JISRF) Classification System for Short Stem Uncemented THA. TSITM Study Group September 2012
10. McTighe T, Stulberg SD, Keppler L, Keggi J, Kennon RT, Brazil D, Aram T, McPherson E. A Classification System for Short Stem Uncemented Total Hip Arthroplasty. *Bone Joint J* 2013 vol 95-B no.SUPP 15 260
11. Mont MA, McGrath MS, Ulrich SD. Metal on Metal total hip resurfacing arthroplasty in presence of extra-articular deformities or implants. *J Bone Joint Surg* 2008; 90-A: 45-57
12. Mont MA, Pivec R, Kimona I, Harwin S. Short stem option for total hip arthroplasty with retained hardware. *Orthopedics* 36.10 (Oct 2013) 770-2
13. Patel RM, Smith MC, Woodward CC, Stulberg SD. Stable fixation of short stem femoral implants in patients 70 years and older. *Clin Orthop Relat Res* (2012) 470:442-449
14. Patel RM, Stulberg SD. The Rationale for short uncemented stems in total hip arthroplasty. *Orthop Clin N Am* 45 (2014) 19-31
15. Pipino F, Keller A. Tissue-sparing surgery: 25 years' experience with femoral neck preserving hip arthroplasty. *J.Orthopaedics and Traumatology* 2006 7:36-41
16. Pipino F, Molfetta L, Grandizio M. Preservation of the femoral neck in hip arthroplasty: results of a 13- to 17 year follow up. *J Orthopaedics and Traumatology* 200 1:31-39
17. Schmidutz F, Beirer M, Weber P, Mazoochian F, Fottner A, Jansson V. Biomechanical reconstruction of the hip: comparison between modular short stem hip arthroplasty and conventional total hip arthroplasty. *International Orthopaedics (SICOT)* (2012) 36:1341-1347
18. Stulberg SD, Patel RM. The Short stem: Promises and Pitfalls. *Bone Joint J* 2013;95-B, SuppleA:57-62



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#### SCHEDULE

##### THURSDAY, NOVEMBER 5

1:00 PM TSA I  
 2:25 PM rTSA  
 3:45 PM Break  
 4:15 PM Point-Counterpoint Debates  
 5:15 PM What Would You Do: Case-Based  
 Presentations  
 6:00 PM Opening Reception

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##### FRIDAY, NOVEMBER 6

7:00 AM Live Surgery  
 8:00 AM Instability  
 9:25 AM Break  
 9:55 AM Point-Counterpoint Debates  
 10:40 AM Rotator Cuff  
 12:00 PM Industry-Sponsored Luncheon  
 Workshops  
 1:20 PM Perioperative Management of the  
 Shoulder Patient  
 2:40 PM How I Do It  
 3:20 PM Break  
 3:50 PM What Would You Do: Case-Based  
 Presentations

##### SATURDAY, NOVEMBER 7

7:00 AM Surgical Skills Cadaver Workshops  
 Small-Group Discussions: Case-Based  
 Reviews  
 10:30 AM Fractures and Dislocations  
 11:50 AM Industry-Sponsored Luncheon  
 Workshops  
 1:10 PM Total Shoulder Arthroplasty II  
 2:30 PM How I Do It  
 3:10 PM Break  
 3:40 PM Point-Counterpoint Debates  
 4:25 PM What Would You Do: Case-Based  
 Presentations  
 5:10 PM Adjourn



# Early Intraprosthetic Dislocation of Dual-Mobility Total Hip Arthroplasty Implant Following Attempted Closed Reduction

Schirmers J<sup>2</sup>, Horazdovsky R<sup>1</sup>, Marston S<sup>1</sup>

**Keywords:** dislocation, dual-mobility, close reduction, total hip

**Level of Evidence:** AAOS Therapeutic Level IV

## Introduction

Introduced in 1974 by Bousquet, the dual-mobility bearing for use in total hip arthroplasty (THA) confers increased jump distance and improved overall stability relative to conventional THA designs [1-3]. The dual-mobility bearing incorporates a relatively small (22-28mm) metal or ceramic femoral head press fit into a larger polyethylene liner which articulates with the acetabular component. Dissociation of the femoral head from the polyethylene liner (intraprosthetic dislocation) is a known late complication thought to be related to polyethylene liner wear and has been previously reported [2-7]. In a consecutive series of 384 primary THAs employing Bousquet's original design, there were 14 intraprosthetic dislocations over 15 years (3.6%). The authors cited polyethylene wear as causative and mean time to intraprosthetic dislocation was 8.9 years [2].

A recent investigation by Hamadouche et al. reported a 2.4% rate of intraprosthetic dislocation among 168 consecutive primary THAs followed for a minimum of 5-years [5]. The dislocations occurred at a mean 5.9 years and were thought to be secondary to wear at the mobile insert. A case report from the UK describes an intraprosthetic dislocation of a dual mobility implant occurring 1.5 years after primary THA [8]. There have been no reports in North America of early intraprosthetic dislocation following use of dual mobility implants for primary THA.

Three recent case reports describe early (within 14 months) intraprosthetic dislocation of the dual mobility

implants following attempted closed reduction of an ipsilateral hip dislocation [4,6-7]. The reports, however, concern patients in which the dual-mobility head was used in an off-label, mix-and-match fashion to revise an existing THA with retention of either the femoral stem [7] or acetabular cup [4,6].

We present a patient with intraprosthetic dislocation following attempted closed reduction of a primarily-implanted dual-mobility THA. To our knowledge, this is the first case of early intraprosthetic dislocation of a primary dual-mobility implant to be reported in North America. The purpose of the current report is to increase awareness of intraprosthetic dislocation and mitigate its risk by recommending that orthopaedic surgeons be involved with any attempted reduction of dual mobility implants.

## Case Report

A sixty-seven-year-old man with a pertinent history of cerebral palsy (CP) presented to an outside hospital after a fall onto his left hip while attempting to rise from a chair. Prior to the fall, the patient was a community ambulator.

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Roentgenograms revealed a displaced, comminuted femoral neck fracture and the patient was transferred to a trauma center for definitive management. The time of orthopaedic consult was twenty-four hours after original injury. Due to the timing and the patient's pre-injury functional status, it was felt a total hip arthroplasty was most appropriate. Due to his history of CP, it was felt that use of a large head with dual mobility would minimize his risk of dislocation. The patient subsequently underwent primary total hip arthroplasty utilizing a posterior approach with implantation of a 56mm press-fit cobalt chrome acetabular shell in anatomic anteversion and a 28mm diameter ceramic femoral head with a 50mm polyethylene insert (Anatomic Dual-Mobility X3; Stryker, Mahwah, New Jersey) (Fig. 1). Grade 3-4 degenerative changes were found anteriorly and superiorly on femoral head. Additionally, two luque wires were placed proximal and distal to the lesser trochanter for fracture prophylaxis per surgeon's routine for hip fracture patients undergoing arthroplasty. The polyethylene and ceramic head were assembled with implant-specific tools according to the manufacture's specifications. The hip was noted to be stable intraoperatively with flexion to 90 degrees, adduction to 20 degrees and internal rotation to 80 degrees with no impingement or subluxation. Both the posterior capsule and short external rotators were repaired. The patient had

an uneventful postoperative course and was discharged on hospital day 5.

On postoperative day 26, the patient presented to the emergency department with left hip pain and inability to bear weight subsequent to a fall out of bed onto his left hip. Imaging revealed a posterior dislocation of the left hip. On initial dislocation films the poly head can be visualized in place on the ceramic femoral head (Fig. 2). Emergency medicine physicians performed closed reduction under



Figure 2: Anteroposterior pelvic film after initial dislocation. The poly head can be visualized in place on the ceramic femoral head.



Figure 1: Post-operative anteroposterior (A) and cross-table lateral (B) views of the hip.

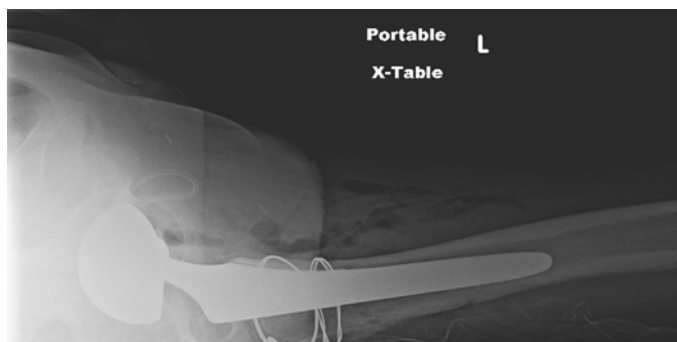


Figure 1B

conscious sedation. Postreduction roentgenograms were read as normal. Retrospective review demonstrates an eccentrically located femoral head and a circular radiolucency overlying the left gluteal musculature (Fig. 3). The patient was discharged with instructions to bear weight as tolerated, limiting hip flexion to less than 70 degrees.

Six weeks after the index procedure, the patient again presented to the emergency department with left hip pain and inability to bear weight after attempting to get into a car. Plain imaging revealed a posterior hip dislocation with the prosthetic head superior and posterior to the acetabular component (Fig. 4). The patient underwent closed reduction with subsequent relocation of the hip in the ER. Post-reduction films were notable for an eccentric position of the femoral head within the acetabular component in addition to a spherical lucency posterior to the acetabulum confirming an intraprostatic dislocation (Fig. 5). The patient returned to the operating theater for revision THA. Intraoperatively, the polyethylene liner was



Figure 3: Anteroposterior hip film after reduction. Note the eccentrically located femoral head and a circular radiolucency of poly head overlying the left gluteal musculature (identified by the arrow).



Figure 4: Anteroposterior pelvic films after the posterior hip dislocation with the prosthetic head superior and posterior to the acetabular component.



Figure 5: Anteroposterior hip films after reduction. Note the eccentric position of the femoral head within the acetabular component in addition to a spherical lucency posterior to the acetabulum confirming an intraprosthetic dislocation (identified by the arrow).

identified within the gluteal musculature, completely dissociated from the femoral head. A trial was done with existing components and the hip was found to be stable with flexion to 90 degrees, adduction to 20 degrees, internal rotation to 70 degrees, with no obvious component failure. Due to concern for damage to the cobalt chrome acetabular shell and ceramic head from articulation over the previous weeks both the femoral head and acetabular components were revised using a 58mm press-fit cobalt chrome acetabular shell and 28mm outer diameter ceramic femoral head with a 52mm polyethylene insert (Anatomic Dual-Mobility X3; Stryker, Mahwah, New Jersey). The CoCr shell was placed with an additional 10 degrees of anteversion and patient had a stable intraoperative exam. He tolerated the procedure well but his postoperative course was complicated by sigmoid volvulus. This resulted in an emergent exploratory laparotomy, a prolonged course in the SICU from which the patient did not recover, and ultimately the death of the patient on post operative day 79 from the index procedure.

## Discussion

This is the first case of early intraprosthetic dislocation of a primary dual-mobility implant to be reported in North America. Previous literature has suggested restricting the use of dual-mobility components in primary THA only to patients at increased risk for dislocation (i.e. patients >75 years of age, those with neuromuscular or cognitive disorders, and patients having an ASA score  $\geq 3$ ) [9]. A dual mobility implant was therefore chosen for this patient with cerebral palsy who is at higher risk for dislocation. Our institution has flat cap pricing contracts and we occasionally use this device in patients felt to have an increased risk of instability.

The patient's diagnosis of cerebral palsy is material to the current discussion, as the risk of THA dislocation is higher in patients with CP [10]. While there have been no large case series analyzing the incidence of dual-mobility THA dislocation in patients with cerebral palsy, a retrospective cohort of eight patients (10 hips) treated with dual-mobility designs reported no dislocations at an average follow-up of 39 months [11].

The posterior approach was utilized in this patient according to the preference of the primary surgeon. An anterior or anterior lateral approach can be considered in patients with increased dislocation risk. However, in a retrospective review of 228 THA revisions in the Swedish Hip Arthroplasty Register using dual mobility implants 56% were performed through a posterior approach and there was no increased incidence of dislocation in this cohort relative to other approaches [12].

Philippot et al. recently postulated three mechanisms of intraprosthetic dislocation after analysis of 81 such cases from a series of 1960 primary dual-mobility THAs implanted between 1985 and 1998 [13]. Type I "pure" dislocation results from wear of the polyethylene retentive rim in an otherwise functional prosthesis; this accounted for 32% of cases. Type II was secondary to extrinsic blocking of the polyethylene liner, for example, by arthrofibrosis or heterotopic ossification; 51% of dislocations were classified as Type II. Finally, Type III was characterized by cup loosening and accounted for 17% of intraprosthetic dislocations. Notably, each of these mechanisms is a late complication with mean onset of 11, 8, and 9 years, respectively.

In North America there are no randomized controlled trials comparing the rate of dislocation among dual-mobility and conventional THA implants. A single non-randomized, retrospective study compared the rate of dislocation of conventional THA and dual-mobility THAs implanted primarily following femoral neck fracture. Among 98

primary THAs at one year there were no dislocations reported in the dual-mobility group compared with 8 of 56 (14%) of the conventional THAs [11]. Moreover, in a recent retrospective comparison of bipolar hemiarthroplasty and dual-mobility THA the authors reported a significantly increased incidence of dislocation among patients treated with bipolar hemiarthroplasty (14.6% vs. 4.5%) [15].

Analogous to the current case, intraprosthetic dislocation of bipolar hemiarthroplasty implants after attempted closed reduction has been described in the French literature [16]. In both cases bipolar hemiarthroplasty was utilized in treating displaced femoral neck fractures. The authors of this report postulate a “bottle-opener” effect where the cup engages the posterior acetabular rim and subsequent limb traction results in dislocation of the intraprosthetic joint. It is reasonable to conclude, although no biomechanical studies have been conducted to address this claim, that the “bottle-opener” effect would only be exaggerated when the relatively smooth posterior acetabular rim is replaced with a metal acetabular component.

In contradistinction to postulated mechanisms of late intraprosthetic dislocation, the current case was likely a direct result of attempted closed reduction with subsequent impingement of the polyethylene head on the acetabular component. The aforementioned case report by Banzhof et al. describes this impingement mechanism leading to early intraprosthetic dislocation following attempted closed reduction [4].

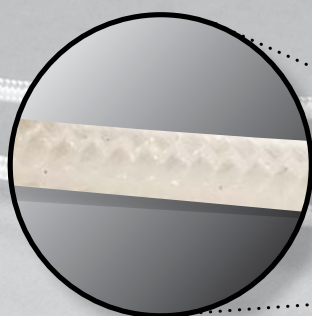
We advise caution with any attempt at closed reduction of dual-mobility implants. In many communities emergency room physicians routinely perform closed reduction of dislocated total hips under sedation without consulting orthopaedics. For patients with a dual-mobility implant and THA dislocation, an orthopaedic surgeon should perform the reduction attempt under general anesthesia with complete muscle relaxation using fluoroscopy. Although an intraprosthetic dislocation could still occur in this setting the risk would be reduced, recognition of the complication immediate, and it would allow for an open reduction under the same anesthetic if required. We recommend advising patients with dual mobility implants that orthopaedic surgeons be involved with any attempted reduction in the event their total hip dislocates to mitigate the risk on an intraprosthetic dislocation. If similar case reports follow in the literature consideration should be made for advising patients with dual-mobility implants to have dislocations addressed in the manner described above.

## References

1. Farizon F, de Lavison R, Azoulay JJ, Bousquet G: Results with a cementless alumina-coated cup with dual mobility: A twelve-year follow-up study. *Int Orthop* 1998, 22(4):219-224.
2. Philippot R, Camilleri JP, Boyer B, Adam P, Farizon F: The use of a dual-articulation acetabular cup system to prevent dislocation after primary total hip arthroplasty: Analysis of 384 cases at a mean follow-up of 15 years. *Int Orthop* 2009, 33(4):927-932.
3. Philippot R, Adam P, Reckhaus M, et al: Prevention of dislocation in total hip revision surgery using a dual mobility design. *Orthop Traumatol Surg Res* 2009, 95(6):407-413.
4. Banzhof JA, Robbins CE, Av Ven, Talmo CT, Bono JV: Femoral head dislodgement complicating use of a dual mobility prosthesis for recurrent instability. *J Arthroplasty* 2013 Mar, 28(3):e1-3. Epub 2012 Dec 21
5. Hamadouche M, Arnould H, Bouxin B: Paper 348: Cementless dual mobility socket in primary THA at a mean 7-year follow-up. 79th Annual Meeting Proceedings. Rosemont, IL, American Academy of Orthopaedic Surgeons 2012, pp 541-542.
6. Riviere C, Lavigne M, Alghamdi A, Vendittoli P: Early Failure of Metal-on-Metal Large-Diameter Head Total Hip Arthroplasty Revised with a Dual-Mobility Bearing; A Case Report. *JBJS Case Connector* 2013 Sep, 3(3):e95 1-6.
7. Ward J, McCardell BR, Hallstrom BR: Complete Dissociation of the Polyethylene Component in a Newly Available Dual-Mobility Bearing Used in Total Hip Arthroplasty; A Case Report. *JBJS Case Connector* 2013 Sep, 3(3):e94 1-4.
8. Mohammed R, Cnudde P: Severe metallosis owing to intraprosthetic dislocation in a failed dual-mobility cup primary total hip arthroplasty. *J Arthroplasty* 2012 Mar, 27(3):e1-3. Epub 2011 Jul 12.
9. Stulberg SD: Dual mobility for chronic hip instability: A solution option. *Orthopedics* 2010, 33(9):637
10. Buly RL, Huo M, Root L, Binzer T, Wilson PD, Jr: Total hip arthroplasty in cerebral palsy. Long-term follow-up results. *Clin Orthop Res* 1993, 296:148-153.
11. Sanders RJ, Swierstra BA, Goosen JH: The use of a dual-mobility concept in total hip arthroplasty patients with spastic disorders: No dislocations in a series of ten cases at midterm follow-up. *Arch Orthop Trauma Surg* 2013 Jul, 133(7):1011-1016.
12. Hailer NP, Weiss RJ, Stark A, Kärrholm J: Dual-mobility cups for revision due to instability are associated with a low rate of re-revisions due to dislocation: 228 patients from the Swedish Hip Arthroplasty Register. *Acta Orthop* 2012 Dec, 83(6):566-571.
13. Philippot R, Boyer B, Farizon F: Intraprosthetic dislocation: a specific complication of the dual-mobility system. *Clin Orthop Relat Res* 2013 Mar, 471(3):965-970. Epub 2012 Oct 10.
14. Tarasevicius S, Busevicius M, Robertsson O, Wingstrand H: Dual mobility cup reduces dislocation rate after arthroplasty for femoral neck fracture. *BMC Musculoskelet Disord* 2010, 11:175.
15. Bensen AS, Jakobsen T, Krarup N: Dual mobility cup reduces dislocation and reoperation when used to treat displaced femoral neck fractures. *Int Orthop* 2014 Jun, 38(6):1241-1245.
16. Loubignac F, Boissier F: Cup dissociation after reduction of a dislocated hip hemiarthroplasty. *Rev Chir Orthop Reparatrice Appar Mot* 1997, 83(5):469-472.



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1. Callaghan et al (1997) Contribution of cable debris generation to accelerated polyethylene wear. *Clin Orthop* 344:20.
2. Jacobs et al (2004). Accumulation in liver and spleen of metal particles generated at nonbearing surfaces in hip arthroplasty. *J Arthroplasty* 19:94.
3. Sarin, Mattchen, Hack (2005) Novel iso-elastic cerclage cable for treatment of fractures. ORS. Washington, DC. 739.
4. Della Valle et al (2010) Early experience with a novel nonmetallic cable. *Clinical Orthop* 468:2382.
5. Edwards et al (2011) Utility of polymer cerclage cables in revision shoulder arthroplasty. *Orthopedics* 34:264.
6. Berend, Lombardi et al (2014) Polymer Cable/Grip-Plate System with Locking Screws for Stable Fixation to Promote Healing of Trochanteric Osteotomies or Fractures in Revision Total Hip Arthroplasty. *Surg Tech Intl.* 25:227.



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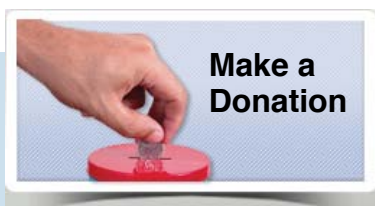
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This phase will include an expansion of our world renowned executive health and wellness practice, The Greenbrier Clinic, which will be bolstered by a world-class sports medicine program, including an orthopedic surgery center and athletic performance/rehabilitation facility, all led by the Founder of the American Sports Medicine Institute, Dr. Jim Andrews and Chair of Cleveland Clinic Innovations, Thomas Graham. Rounding out the Institute's services will be a first-



in-class plastic and cosmetic surgery and Lifestyle Enhancement Academy, helping people look and feel their best. Physicians, universities, research foundations, medical journals and other healthcare industry leaders, all of whom are on the cutting edge of medical technology, research and care, have committed to join the project and establish an international research and education destination or "think tank" to stimulate research, drive innovation, force change and redefine how the world approaches health, wellness and longevity.

The Institute's facility, designed by Willie Stokes, will feature Georgian architecture similar to the resort's façade, a replica of the Springhouse, the site of the famous sulphur springs and special guests suites for patients and their families. Jack Diamond, President and CEO, and Mark Krohn, COO, are leading the development of this exciting project and are actively looking for other physicians and medical thought leaders to be involved.

For more information, please contact:

Mark E. Krohn, Chief Operating Officer  
Greenbrier Medical Institute, 330-697-6581  
[mekrohn@bmdllc.com](mailto:mekrohn@bmdllc.com)

# Do You ResearchGate?

**With** the start of 2015 comes our fourth full year of publishing the Reconstructive Review. In that time of establishing our niche in the online orthopaedic journal market I have discovered what I think is a very useful website for collaborating with fellow researchers around the world called ResearchGate (<http://www.researchgate.net>).

According to Wikipedia “ResearchGate is a social networking site for scientists and researchers to share papers, ask and answer questions, and find collaborators.” Current estimates puts the total number of users at over 6 million. While this is hardly the numbers of users that sites it has been compared to such as Twitter, LinkedIn, or Facebook (288M, 300M, and 1.23B respectively) I believe ResearchGate has great potential to continue to grow as significantly as it has over the past seven years.

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**Timothy McTighe, Dr. HS (hc)**  
Executive Director, JISRF  
& Editor-in-Chief  
Reconstructive Review





# Commentary

By

David Campbell, MD  
Wakefield Orthopaedic Clinic  
Adelaide, South Australia



## Is there an optimum Taper Design?



Improved biomaterials have dramatically increased hip arthroplasty survival and there has been a measurable reduction in the two main causes of revision. Since the introduction of cross-linked polyethylenes the Australian registry reports a reduction of loosening/lysis related revisions from 4.2% to 1.5% at 12 years. As a consequence of the increased femoral head diameters used with cross-linked polyethylenes the rate of revision for dislocation has fallen from 0.7% to 0.4% at 12 years. [1] With the two most frequent causes of revision decreasing our attention has been directed to the next most frequent causes of failure of a total hip arthroplasty.

Trunnionosis is a previously obscure mode of failure of the head/neck junction that has probably escaped the attention of most arthroplasty surgeons with many cases of wear and lysis being attributed to the more frequent etiology of articular surface wear. McTighe et al [2] describe the clinical and tribological implications of wear of the trunnion that has been associated with sporadic cases of soft tissue tumours caused by metallic debris. The increased rate of

failure of large metal on metal head bearings is now well described and the greater failure rate observed when a conventional stem was used compared to a resurfacing femoral component led to the focus of the taper as an important contributor to metal ion pathology. [1] Trunnionosis is more apparent in large diameter metal-on-metal bearings due to the increased friction and stress upon the taper but they are also seen in large diameter metal and polyethylene bearings (figure 1). In a personal series, the incidence of trunnionosis as a cause of revision is estimated to be 3 per 1000.

An obvious challenge is to improve the characteristics of tapers used in orthopaedic surgery. The Morse taper developed in the mid-1860s (by Stephen Morse a machinist) for use in the machine tool industry, and has evolved and been adopted by the orthopaedic industry one hundred years later. It was first described in orthopaedic surgery by Mittelmeier in 1974 as a means of securing a ceramic head to the femoral component. Machine tapers are classified by the American standards Association as self holding or self releasing (steep) tapers. Self holding tapers typically have a small taper angle of two or 3° and remain in position because of the wedging action of the small taper angle. The original 1860s Morse taper had an angle of 2° 50" and most orthopaedic tapers have an angle of 5 to 18°.

Other trunnion characteristics include length, area of interference, material, surface finish, taper mismatch and the relationship of these factors to orthopaedics is highlighted in McTighe et al's paper [2]. Sadly the introduction of tapers to orthopaedic surgery has not been consistent or standardized. The most frequently used 12/14 taper may have been a reasonable compromise when smaller femoral heads such as 22-28mm were in frequent use. With the increased use of larger diameter femoral heads there is no longer a requirement to accommodate a smaller taper size and it may be an opportune time to rethink the optimal taper for total hip arthroplasty. A larger diameter taper of increased length and surface area is appealing. The use of a standardized 'off-the-shelf' femoral taper would be of enormous benefit to implant vendors and orthopaedic surgeons and would be especially helpful to minimize the risk of implanting mismatched components. Perhaps surgeons should drive this initiative and start the discussion through our professional societies.

### References

1. (AOANJRR), A.O.A.N.J.R.R., Annual Report 2013. 2013, Australian Orthopaedic Association National Joint Registry Australian Joint replacement registry.
2. McTighe T, Brazil D, Clarke I, Keppler L, Keggi J, Tkach T, McPherson E. Metallic Modular Taper Junctions in Total Hip Arthroplasty. RR Vol5, Number 2, July 2015. Doi: <http://dx.doi.org/10.15438/rr.5.2.108>



Figure 1. Example of trunnionosis. Excessive wear of a titanium on cobalt chromium taper combined with a large diameter femoral head articulating on polyethylene. Note the destruction of the worn taper leading to secondary neck impingement on the femoral head and ultimately complete dissociation.



# Reconstructive Review

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### Disclosure for Authors

Article 1, page 13.

McPherson [3], Vaughn [1], Keppler [3], Brazil [3], McTighe [3]

Article 2, page 19.

Burton [1], Medina [1], Burgett-Moreno [1], Donaldson [1], Clarke [1]

Article 3, page 25.

Donaldson [1], Burgett-Moreno [1], Clarke [1]

Article 4, page 29.

McTighe [3], Brazil [3], Clarke [1], Keppler [3], Keggi [3], Tkach [3], McPherson [3]

Article 5, page 43.

Gamboa [1], Campbell [1], Lewis [1]

Article 6, page 47.

Schirmers [1], Horazdovsky [1], Marston [1]

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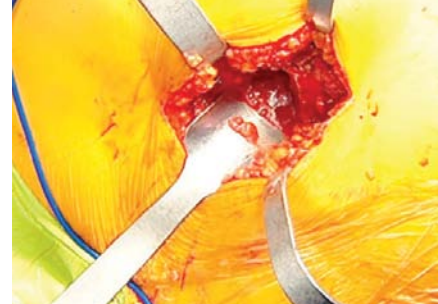
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